



US006370371B1

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

(10) **Patent No.:** US 6,370,371 B1  
(45) **Date of Patent:** \*Apr. 9, 2002

(54) **APPLICATIONS OF UNIVERSAL  
FREQUENCY TRANSLATION**

(75) Inventors: **David F. Sorrells; Michael J. Bultman**, both of Jacksonville; **Robert W. Cook**, Switzerland; **Richard C. Looke; Charley D. Moses, Jr.**, both of Jacksonville, all of FL (US)

(73) Assignee: **ParkerVision, Inc.**, Jacksonville, FL (US)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/261,129**  
(22) Filed: **Mar. 3, 1999**

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 09/176,027, filed on Oct. 21, 1998, now abandoned.

(51) **Int. Cl.<sup>7</sup>** ..... **H04B 1/26; H04B 1/40**  
(52) **U.S. Cl.** ..... **455/323; 455/313; 327/113**  
(58) **Field of Search** ..... **327/113; 455/313, 455/323, 333**

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

2,057,613 A	10/1936	Gardner	250/8
2,241,078 A	5/1941	Vreeland	179/15
2,270,385 A	1/1942	Skillman	179/15
2,283,575 A	5/1942	Roberts	250/6
2,358,152 A	9/1944	Earp	179/171.5
2,410,350 A	10/1946	Labin et al.	179/15
2,451,430 A	10/1948	Barone	250/8
2,462,069 A	2/1949	Chatterjea et al.	250/17
2,462,181 A	2/1949	Grosselfinger	250/17
2,472,798 A	6/1949	Fredendall	178/44

2,497,859 A	2/1950	Boughtwood et al.	250/8
2,499,279 A	2/1950	Peterson	332/41
2,802,208 A	8/1957	Hobbs	343/176
2,985,875 A	5/1961	Grisdale et al.	343/100
3,023,309 A	2/1962	Foulkes	250/17
3,069,679 A	12/1962	Sweeney et al.	343/200
3,104,393 A	9/1963	Vogelman	343/200
3,114,106 A	12/1963	McManus	325/56
3,118,117 A	1/1964	King et al.	332/22
3,226,643 A	12/1965	McNair	325/40

(List continued on next page.)

**FOREIGN PATENT DOCUMENTS**

DE	42 37 692 C1	3/1994	H04B/1/26
EP	0 035 166 A1	9/1981	H04B/1/26
EP	0 099 265 A1	1/1984	H03D/3/04

(List continued on next page.)

**OTHER PUBLICATIONS**

Translation of Specification and Claims of FR Patent No. 2245130, 3 pages.

Aghvami, H. et al., "Land Mobile Satellites Using the Highly Elliptic Orbits— The UK T-SAT Mobile Payload," *4<sup>th</sup> International Conf. On Satellite Systems for Mobile Communications and Navigation*, Oct. 17–19, 1988, pp. 147–153.

Akers, N.P. et al., "RF Sampling Gates: a Brief Review," *IEE Proc.*, vol. 133, Part A, No. 1, Jan. 1986, pp. 45–49.

(List continued on next page.)

*Primary Examiner*—Dwayne Bost

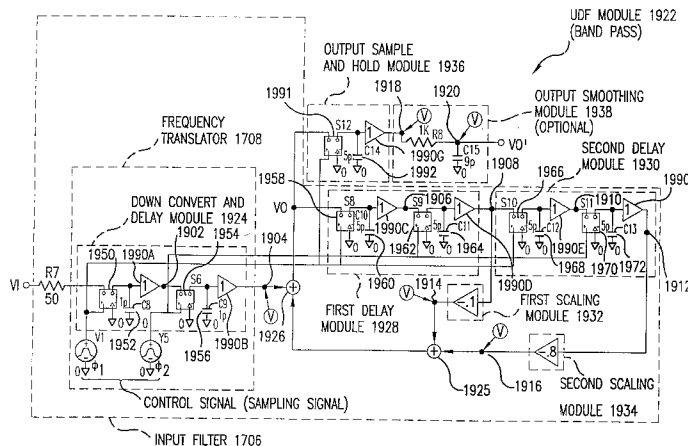
*Assistant Examiner*—Miguel D. Green

(74) *Attorney, Agent, or Firm*—Sterne, Kessler, Goldstein & Fox, P.L.L.

(57) **ABSTRACT**

Frequency translation and applications of same are described herein. Such applications include, but are not limited to, frequency down-conversion, frequency up-conversion, enhanced signal reception, unified down-conversion and filtering, and combinations and applications of same.

**68 Claims, 58 Drawing Sheets**



## U.S. PATENT DOCUMENTS

3,258,694 A	6/1966	Shepherd .....	325/145	4,521,892 A	6/1985	Vance et al. ....	375/88
3,383,598 A	5/1968	Sanders .....	325/163	4,563,773 A	1/1986	Dixon, Jr. et al. ....	455/327
3,384,822 A	5/1968	Miyagi .....	325/30	4,577,157 A	3/1986	Reed .....	329/50
3,454,718 A	7/1969	Perreault .....	178/66	4,583,239 A	4/1986	Vance .....	375/94
3,523,291 A	8/1970	Pierret .....	340/347	4,591,736 A	5/1986	Hirao et al. ....	307/267
3,548,342 A	12/1970	Maxey .....	332/9	4,602,220 A	7/1986	Kurihara .....	331/19
3,555,428 A	1/1971	Perreault .....	325/320	4,603,300 A	7/1986	Welles, II et al. ....	329/50
3,617,892 A	11/1971	Hawley et al. ....	325/145	4,612,464 A	9/1986	Ishikawa et al. ....	307/496
3,621,402 A	11/1971	Gardner .....	328/37	4,612,518 A	9/1986	Gans et al. ....	332/21
3,623,160 A	11/1971	Giles et al. ....	340/347 DA	4,616,191 A	10/1986	Galani et al. ....	331/4
3,626,417 A	12/1971	Gilbert .....	343/203	4,621,217 A	11/1986	Saxe et al. ....	315/1
3,629,696 A	12/1971	Bartelink .....	324/57 R	4,628,517 A	12/1986	Schwarz et al. ....	375/40
3,662,268 A	5/1972	Gans et al. ....	325/56	4,634,998 A	1/1987	Crawford .....	331/1 A
3,689,841 A	9/1972	Bello et al. ....	325/39	4,648,021 A	3/1987	Alberkrack .....	363/157
3,714,577 A	1/1973	Hayes .....	325/145	4,651,034 A	3/1987	Sato .....	307/556
3,717,844 A	2/1973	Barret et al. ....	340/5 R	4,653,117 A	3/1987	Heck .....	455/209
3,735,048 A	8/1973	Tomsa et al. ....	179/15 BM	4,675,882 A	6/1987	Lillie et al. ....	375/80
3,806,811 A	4/1974	Thompson .....	325/146	4,688,253 A	8/1987	Gumm .....	381/7
3,868,601 A	2/1975	MacAfee .....	332/45	4,716,376 A	12/1987	Daudelin .....	329/107
3,949,300 A	4/1976	Sadler .....	325/31	4,716,388 A	12/1987	Jacobs .....	333/173
3,967,202 A	6/1976	Batz .....	325/31	4,718,113 A	1/1988	Rother et al. ....	455/209
3,980,945 A	9/1976	Bickford .....	325/30	4,726,041 A	2/1988	Prohaska et al. ....	375/91
3,987,280 A	10/1976	Bauer .....	235/150.53	4,733,403 A	3/1988	Simone .....	375/103
3,991,277 A	11/1976	Hirata .....	179/15 FD	4,734,591 A	3/1988	Ichitsubo .....	307/219.1
4,003,002 A	1/1977	Snijders et al. ....	332/10	4,737,969 A	4/1988	Steel et al. ....	375/67
4,013,966 A	3/1977	Campbell .....	325/363	4,743,858 A	5/1988	Everard .....	330/10
4,017,798 A	4/1977	Gordy et al. ....	325/42	4,745,463 A	5/1988	Lu .....	358/23
4,019,140 A	4/1977	Swerdlow .....	322/65	4,751,468 A	6/1988	Agoston .....	328/133
4,032,847 A	6/1977	Unkauf .....	325/323	4,757,538 A	7/1988	Zink .....	381/7
4,035,732 A	7/1977	Lohrmann .....	325/446	4,768,187 A	8/1988	Marshall .....	370/69.1
4,047,121 A	9/1977	Campbell .....	331/76	4,769,612 A	9/1988	Tamakoshi et al. ....	328/167
4,051,475 A	9/1977	Campbell .....	343/180	4,785,463 A	11/1988	Janc et al. ....	375/1
4,066,841 A	1/1978	Young .....	178/66 R	4,791,584 A	12/1988	Greivenkamp, Jr. ....	364/525
4,066,919 A	1/1978	Huntington .....	307/353	4,801,823 A	1/1989	Yokoyama .....	307/353
4,081,748 A	3/1978	Batz .....	325/56	4,806,790 A	2/1989	Sone .....	307/353
4,130,765 A	12/1978	Arakelian et al. ....	307/220 R	4,810,904 A	3/1989	Crawford .....	307/353
4,130,806 A	12/1978	Van Gerwen et al. ....	325/487	4,810,976 A	3/1989	Cowley et al. ....	331/117 R
4,142,155 A	2/1979	Adachi .....	325/47	4,811,362 A	3/1989	Yester, Jr. et al. ....	375/75
4,170,764 A	10/1979	Salz et al. ....	332/17	4,816,704 A	3/1989	Fiori, Jr. ....	307/519
4,204,171 A	5/1980	Sutphin, Jr. ....	328/167	4,819,252 A	4/1989	Christopher .....	375/122
4,210,872 A	7/1980	Gregorian .....	330/9	4,833,445 A	5/1989	Buchele .....	341/118
4,245,355 A	1/1981	Pascoe et al. ....	455/326	4,841,265 A	6/1989	Watanabe et al. ....	333/194
4,253,066 A	2/1981	Fisher et al. ....	329/50	4,862,121 A	8/1989	Hochschild et al. ....	333/173
4,253,067 A	2/1981	Caples et al. ....	329/110	4,868,654 A	9/1989	Juri et al. ....	358/133
4,253,069 A	2/1981	Nossek .....	330/107	4,870,659 A	9/1989	Oishi et al. ....	375/82
4,308,614 A	12/1981	Fisher et al. ....	370/119	4,871,987 A	10/1989	Kawase .....	332/100
4,320,361 A	3/1982	Kikkert .....	332/16 R	4,885,587 A	12/1989	Wiegand et al. ....	42/14
4,320,536 A	3/1982	Dietrich .....	455/325	4,885,756 A	12/1989	Fontanes et al. ....	375/82
4,346,477 A	8/1982	Gordy .....	455/257	4,888,557 A	12/1989	Puckette, IV et al. ....	329/341
4,355,401 A	10/1982	Ikoma et al. ....	375/5	4,890,302 A	12/1989	Muilwijk .....	375/80
4,356,558 A	10/1982	Owen et al. ....	364/724	4,893,316 A	1/1990	Janc et al. ....	375/44
4,360,867 A	11/1982	Gonda .....	363/158	4,893,341 A	1/1990	Gehring .....	381/7
4,363,132 A	12/1982	Collin .....	455/52	4,894,766 A	1/1990	De Agro .....	363/159
4,365,217 A	12/1982	Berger et al. ....	333/165	4,896,152 A	1/1990	Tiemann .....	340/853
4,370,572 A	1/1983	Cosand et al. ....	307/353	4,902,979 A	2/1990	Puckette, IV .....	329/343
4,389,579 A	6/1983	Stein .....	307/353	4,908,579 A	3/1990	Tawfik et al. ....	328/167
4,392,255 A	7/1983	Del Giudice .....	455/328	4,910,752 A	3/1990	Yester, Jr. et al. ....	375/75
4,393,395 A	7/1983	Hacke et al. ....	358/23	4,914,405 A	4/1990	Wells .....	331/25
4,430,629 A	2/1984	Betzl et al. ....	333/165	4,920,510 A	4/1990	Senderowicz et al. ....	364/825
4,446,438 A	5/1984	Chang et al. ....	328/127	4,922,452 A	5/1990	Larsen et al. ....	365/45
4,456,990 A	6/1984	Fisher et al. ....	370/119	4,931,921 A	6/1990	Anderson .....	363/163
4,472,785 A	9/1984	Kasuga .....	364/718	4,943,974 A	7/1990	Motamedi .....	375/1
4,479,226 A	10/1984	Prabhu et al. ....	375/1	4,944,025 A	7/1990	Gehring et al. ....	455/207
4,481,490 A	11/1984	Huntley .....	332/41	4,955,079 A	9/1990	Connerney et al. ....	455/325
4,481,642 A	11/1984	Hanson .....	375/9	4,965,467 A	10/1990	Biliterijst .....	307/352
4,485,488 A	11/1984	Houdart .....	455/327	4,967,160 A	10/1990	Quievvy et al. ....	328/16
4,504,803 A	3/1985	Lee et al. ....	332/31 R	4,970,703 A	11/1990	Hariharan et al. ....	367/138
4,517,519 A	5/1985	Mukaiyama .....	329/126	4,982,353 A	1/1991	Jacob et al. ....	364/724.1
4,517,520 A	5/1985	Ogawa .....	329/145	4,984,077 A	1/1991	Uchida .....	358/140
4,518,935 A	5/1985	van Roermund .....	333/173	4,995,055 A	2/1991	Weinberger et al. ....	375/5
				5,003,621 A	3/1991	Gailus .....	455/209

5,005,169 A	4/1991	Bronder et al. ....	370/76	5,416,803 A	5/1995	Janer .....	375/324
5,006,810 A	4/1991	Popescu .....	328/167	5,422,913 A	6/1995	Wilkinson .....	375/347
5,010,585 A	4/1991	Garcia .....	455/118	5,423,082 A	6/1995	Cygan et al. ....	455/126
5,014,304 A	5/1991	Nicollini et al. ....	379/399	5,428,638 A	6/1995	Cioffi et al. ....	375/224
5,015,963 A	5/1991	Sutton .....	329/361	5,428,640 A	6/1995	Townley .....	375/257
5,017,924 A	5/1991	Guiberteau et al. ....	342/195	5,434,546 A	7/1995	Palmer .....	332/151
5,020,149 A	5/1991	Hemmie .....	455/325	5,438,692 A	8/1995	Mohindra .....	455/324
5,020,154 A	5/1991	Zierhut .....	455/608	5,444,415 A	8/1995	Dent et al. ....	329/302
5,052,050 A	9/1991	Collier et al. ....	455/296	5,444,416 A	8/1995	Ishikawa et al. ....	39/341
5,065,409 A	11/1991	Hughes et al. ....	375/91	5,444,865 A	8/1995	Heck et al. ....	455/86
5,083,050 A	1/1992	Vasile .....	307/529	5,446,421 A	8/1995	Kechkaylo .....	332/100
5,091,921 A	2/1992	Minami .....	375/88	5,446,422 A	8/1995	Mattila et al. ....	332/103
5,095,533 A	3/1992	Loper et al. ....	455/245	5,448,602 A	9/1995	Ohmori et al. ....	375/347
5,095,536 A	3/1992	Loper .....	455/324	5,451,899 A	9/1995	Lawton .....	329/302
5,111,152 A	5/1992	Makino .....	329/300	5,454,007 A	9/1995	Dutta .....	375/322
5,113,094 A	5/1992	Grace et al. ....	307/529	5,454,009 A	9/1995	Fruit et al. ....	372/202
5,113,129 A	5/1992	Hughes .....	323/316	5,463,356 A	10/1995	Palmer .....	332/117
5,115,409 A	5/1992	Stapp .....	364/841	5,463,357 A	10/1995	Hobden .....	332/151
5,122,765 A	6/1992	Pataut .....	332/105	5,465,071 A	11/1995	Kobayashi et al. ....	329/315
5,124,592 A	6/1992	Hagino .....	307/520	5,465,410 A	11/1995	Hiben et al. ....	455/266
5,126,682 A	6/1992	Weinberg et al. ....	329/304	5,465,415 A	11/1995	Bien .....	455/326
5,136,267 A	8/1992	Cabot .....	333/174	5,471,162 A	11/1995	McEwan .....	327/92
5,140,705 A	8/1992	Kosuga .....	455/318	5,479,120 A	12/1995	McEwan .....	327/91
5,150,124 A	9/1992	Moore et al. ....	342/68	5,479,447 A	12/1995	Chow et al. ....	375/260
5,151,661 A	9/1992	Caldwell et al. ....	328/14	5,483,193 A	1/1996	Kennedy et al. ....	329/300
5,159,710 A	10/1992	Cusdin .....	455/304	5,483,549 A	1/1996	Weinberg et al. ....	375/200
5,170,414 A	12/1992	Silvian .....	375/59	5,483,691 A	1/1996	Heck et al. ....	455/234.2
5,172,070 A	12/1992	Hiraiwa et al. ....	329/304	5,490,173 A	2/1996	Whikehart et al. ....	375/316
5,191,459 A	3/1993	Thompson et al. ....	359/133	5,493,581 A	2/1996	Young et al. ....	375/350
5,204,642 A	4/1993	Ashgar et al. ....	331/135	5,493,721 A	2/1996	Reis .....	455/339
5,212,827 A	5/1993	Meszko et al. ....	455/219	5,495,200 A	2/1996	Kwan et al. ....	327/554
5,214,787 A	5/1993	Karkota, Jr. ....	455/3.2	5,495,202 A	2/1996	Hsu .....	327/113
5,220,583 A	6/1993	Solomon .....	375/82	5,495,500 A	2/1996	Jovanovich et al. ....	375/206
5,220,680 A	6/1993	Lee .....	455/102	5,499,267 A	3/1996	Ohe et al. ....	375/206
5,222,144 A	6/1993	Whikehart .....	381/15	5,500,758 A	3/1996	Thompson et al. ....	359/189
5,230,097 A	7/1993	Currie et al. ....	455/226.1	5,515,014 A	5/1996	Troutman .....	332/178
5,239,686 A	8/1993	Downey .....	455/78	5,517,688 A	5/1996	Fajen et al. ....	455/333
5,241,561 A	8/1993	Barnard .....	375/1	5,519,890 A	5/1996	Pinckley .....	455/307
5,249,203 A	9/1993	Loper .....	375/97	5,523,719 A	6/1996	Longo et al. ....	327/557
5,251,218 A	10/1993	Stone et al. ....	370/120	5,523,726 A	6/1996	Kroeger et al. ....	332/103
5,251,232 A	10/1993	Nonami .....	375/5	5,523,760 A	6/1996	McEwan .....	342/89
5,260,970 A	11/1993	Henry et al. ....	375/10	5,539,770 A	7/1996	Ishigaki .....	375/206
5,263,194 A	11/1993	Ragan .....	455/316	5,555,453 A	9/1996	Kajimoto et al. ....	455/266
5,263,196 A	11/1993	Jasper .....	455/324	5,557,641 A	9/1996	Weinberg .....	375/295
5,267,023 A	11/1993	Kawasaki .....	358/23	5,557,642 A	9/1996	Williams .....	375/316
5,278,826 A	1/1994	Murphy et al. ....	370/76	5,563,550 A	10/1996	Toth .....	329/347
5,282,023 A	1/1994	Scarpa .....	358/36	5,574,755 A	11/1996	Persico .....	375/295
5,287,516 A	2/1994	Schaub .....	375/88	5,579,341 A	11/1996	Smith et al. ....	375/267
5,293,398 A	3/1994	Hamao et al. ....	375/1	5,579,347 A	11/1996	Lindquist et al. ....	375/346
5,303,417 A	4/1994	Laws .....	455/314	5,584,068 A	12/1996	Mohindra .....	455/324
5,307,517 A	4/1994	Rich .....	455/306	5,592,131 A	1/1997	Labreche et al. ....	332/103
5,315,583 A	5/1994	Murphy et al. ....	370/18	5,602,847 A	2/1997	Pagano et al. ....	370/484
5,321,852 A	6/1994	Seong .....	455/182.1	5,602,868 A	2/1997	Wilson .....	375/219
5,325,204 A	6/1994	Scarpa .....	348/607	5,604,592 A	2/1997	Kotidis et al. ....	356/357
5,337,014 A	8/1994	Najle et al. ....	324/613	5,604,732 A	2/1997	Kim et al. ....	370/342
5,339,054 A	8/1994	Taguchi .....	332/100	5,608,531 A	3/1997	Honda et al. ....	386/1
5,339,459 A	8/1994	Schiltz et al. ....	455/333	5,610,946 A	3/1997	Tanaka et al. ....	375/269
5,353,306 A	10/1994	Yamamoto .....	375/14	RE35,494 E	4/1997	Nicollini .....	327/554
5,355,114 A	10/1994	Sutterlin et al. ....	340/310 A	5,617,451 A	4/1997	Mimura et al. ....	375/340
5,361,408 A	11/1994	Watanabe et al. ....	455/324	5,619,538 A	4/1997	Sempel et al. ....	375/328
5,369,800 A	11/1994	Takagi et al. ....	455/59	5,621,455 A	4/1997	Rogers et al. ....	348/6
5,375,146 A	12/1994	Chalmers .....	375/103	5,630,227 A	5/1997	Bella et al. ....	455/324
5,379,040 A	1/1995	Mizomoto et al. ....	341/143	5,638,396 A	6/1997	Kilmek .....	372/92
5,379,141 A	1/1995	Thompson et al. ....	359/125	5,640,415 A	6/1997	Pandula .....	375/202
5,388,063 A	2/1995	Takatori et al. ....	364/724.17	5,640,424 A	6/1997	Banavong et al. ....	375/316
5,390,364 A	2/1995	Webster et al. ....	455/52.3	5,640,428 A	6/1997	Abe et al. ....	375/334
5,400,084 A	3/1995	Scarpa .....	348/624	5,640,698 A	6/1997	Shen et al. ....	455/323
5,404,127 A	4/1995	Lee et al. ....	340/310.02	5,648,985 A	7/1997	Bjerede et al. ....	375/219
5,410,541 A	4/1995	Hotto .....	370/76	5,650,785 A	7/1997	Rodal .....	342/357
5,410,743 A	4/1995	Seely et al. ....	455/326	5,661,424 A	8/1997	Tang .....	327/105
5,412,352 A	5/1995	Graham .....	332/103	5,663,878 A	9/1997	Walker .....	363/159

5,663,986 A	9/1997	Striffler .....	375/260	5,909,447 A	6/1999	Cox et al. ....	370/508
5,668,836 A	9/1997	Smith et al. ....	375/316	5,911,116 A	6/1999	Nosswitz .....	455/83
5,675,392 A	10/1997	Nayebi et al. ....	348/584	5,911,123 A	6/1999	Shaffer et al. ....	455/554
5,680,078 A	10/1997	Ariie .....	332/178	5,914,622 A	6/1999	Inoue .....	327/172
5,680,418 A	10/1997	Croft et al. ....	375/346	5,920,199 A	7/1999	Sauer .....	324/678
5,689,413 A	11/1997	Jaramillo et al. ....	363/146	5,933,467 A	8/1999	Sehier et al. ....	375/350
5,694,096 A	12/1997	Ushiroku et al. ....	333/195	5,943,370 A	8/1999	Smith .....	375/334
5,699,006 A	12/1997	Zelev et al. ....	327/341	5,952,895 A	9/1999	McCune, Jr. et al. ....	332/128
5,705,955 A	1/1998	Freeburg et al. ....	331/14	5,953,642 A	9/1999	Feldtkeller et al. ....	455/195.1
5,710,998 A	1/1998	Opas .....	455/324	5,960,033 A	9/1999	Shibano et al. ....	375/207
5,714,910 A	2/1998	Skoczen et al. ....	331/3	6,028,887 A	* 2/2000	Harrison et al. ....	375/206
5,715,281 A	2/1998	Bly et al. ....	375/344	6,041,073 A	3/2000	Davidovici et al. ....	375/148
5,721,514 A	2/1998	Crockett et al. ....	331/3	6,054,889 A	4/2000	Kobayashi .....	327/357
5,724,002 A	3/1998	Hulick .....	329/361	6,084,922 A	7/2000	Zhou et al. ....	375/316
5,724,653 A	3/1998	Baker et al. ....	455/296	6,121,819 A	* 9/2000	Traylor .....	327/359
5,729,577 A	3/1998	Chen .....	375/334	6,125,271 A	9/2000	Rowland et al. ....	455/313
5,729,829 A	3/1998	Talwar et al. ....	455/63	6,144,236 A	* 11/2000	Vice et al. ....	327/113
5,732,333 A	3/1998	Cox et al. ....	455/126	6,144,846 A	* 11/2000	Durec .....	455/323
5,736,895 A	4/1998	Yu et al. ....	327/554	6,147,340 A	11/2000	Levy .....	250/214 R
5,737,035 A	4/1998	Rotzoll .....	348/725	6,147,763 A	11/2000	Steinlechner .....	356/484
5,742,189 A	* 4/1998	Yoshida et al. ....	327/113	6,150,890 A	11/2000	Damgaard et al. ....	331/14
5,748,683 A	5/1998	Smith et al. ....	375/347	6,175,728 B1	* 1/2001	Mitama .....	455/323
5,757,870 A	5/1998	Miya et al. ....	375/367	FOREIGN PATENT DOCUMENTS			
RE35,829 E	6/1998	Sanderford, Jr. ....	375/200	EP	0 193 899 B1	6/1990	..... G01S/7/52
5,760,645 A	6/1998	Comte et al. ....	329/304	EP	0 380 351 A2	8/1990	..... H03H/17/04
5,764,087 A	6/1998	Clark .....	327/105	EP	0 380 351 A3	2/1991	..... H03H/17/04
5,767,726 A	6/1998	Wang .....	327/356	EP	0 411 840 A2	2/1991	..... G01R/33/36
5,768,118 A	6/1998	Faulk et al. ....	363/72	EP	0 423 718 A2	4/1991	..... H04N/7/01
5,768,323 A	6/1998	Kroeger et al. ....	375/355	EP	0 411 840 A3	7/1991	..... G01R/33/36
5,770,985 A	6/1998	Ushiroku et al. ....	333/193	EP	0 486 095 A1	5/1992	..... H03D/3/00
5,771,442 A	6/1998	Wang et al. ....	455/93	EP	0 423 718 A3	8/1992	..... H04N/7/01
5,777,692 A	7/1998	Ghosh .....	348/725	EP	0 512 748 A2	11/1992	..... H04N/9/64
5,777,771 A	7/1998	Smith .....	359/180	EP	0 548 542 A1	6/1993	..... H03B/19/14
5,778,022 A	7/1998	Walley .....	375/206	EP	0 512 748 A3	7/1993	..... H04N/9/64
5,786,844 A	7/1998	Rogers et al. ....	348/6	EP	0 560 228 A1	9/1993	..... H03D/7/12
5,793,801 A	8/1998	Fertner .....	375/219	EP	0 632 288 A2	1/1995	..... G01S/13/75
5,793,818 A	8/1998	Claydon et al. ....	375/326	EP	0 411 840 B1	10/1995	..... G01R/33/36
5,802,463 A	9/1998	Zuckerman .....	455/208	EP	0 696 854 A1	2/1996	..... H04B/1/26
5,809,060 A	9/1998	Cafarella et al. ....	375/206	EP	0 632 288 A3	7/1996	..... G01S/13/75
5,812,546 A	9/1998	Zhou et al. ....	370/342	EP	0 486 095 B1	2/1997	..... H03D/3/00
5,818,582 A	10/1998	Fernandez et al. ....	356/318	EP	0 782 275 A2	7/1997	..... H04B/7/02
5,818,869 A	10/1998	Miya et al. ....	375/206	EP	0 785 635 A1	7/1997	..... H04B/1/713
5,825,254 A	10/1998	Lee .....	331/25	EP	0 795 978 A2	9/1997	..... H04L/5/06
5,834,985 A	11/1998	Sundegård .....	332/100	EP	0 837 565 A1	4/1998	..... H04B/1/69
5,844,449 A	12/1998	Abeno et al. ....	332/105	EP	0 862 274 A1	9/1998	..... H03M/1/06
5,859,878 A	* 1/1999	Philips et al. ....	375/316	EP	0 874 499 A2	10/1998	..... H04L/25/06
5,864,754 A	1/1999	Hotto .....	455/280	EP	0 512 748 B1	11/1998	..... H04N/9/64
5,872,446 A	2/1999	Cranford, Jr. et al. ....	323/315	FR	2 245 130	4/1975	..... H03K/5/13
5,881,375 A	3/1999	Bonds .....	455/118	FR	2 743 231 A1	7/1997	..... H04B/7/12
5,892,380 A	4/1999	Quist .....	327/172	GB	2 161 344 A	1/1986	..... H04B/7/12
5,894,239 A	4/1999	Bonaccio et al. ....	327/176	GB	2 215 945 A	9/1989	..... H04L/27/00
5,896,562 A	4/1999	Heinonen .....	455/76	JP	2-39632	2/1990	..... H04B/7/12
5,900,747 A	5/1999	Brauns .....	327/9	JP	2-131629	5/1990	..... H04B/7/12
5,901,054 A	5/1999	Leu et al. ....	363/41	JP	2-276351	11/1990	..... H04L/27/22
5,901,187 A	5/1999	Iinuma .....	375/347	WO	WO 80/01633 A1	8/1980	..... H04J/1/08
5,901,344 A	5/1999	Opas .....	455/76	WO	WO 94/05087 A1	3/1994	..... H03M/1/00
5,901,347 A	5/1999	Chambers et al. ....	455/234.1	WO	WO 96/02977 A1	2/1996	..... H04B/1/26
5,901,348 A	5/1999	Bang et al. ....	455/254	WO	WO 96/08078 A1	3/1996	..... H03D/3/00
5,901,349 A	5/1999	Guegnaud et al. ....	455/302	WO	WO 96/39750 A1	12/1996	..... H04B/1/26
5,903,178 A	5/1999	Miyatsuji et al. ....	327/308	WO	WO 97/38490 A1	10/1997	..... H03K/7/00
5,903,187 A	5/1999	Claverie et al. ....	329/342	WO	WO-97/38490 A1	* 10/1997	..... H03K/7/00
5,903,196 A	5/1999	Salvi et al. ....	331/16	WO	WO 98/00953 A1	1/1998	..... H04L/27/26
5,903,421 A	5/1999	Furutani et al. ....	361/58	WO	WO 98/24201 A1	6/1998	..... H04H/1/00
5,903,553 A	5/1999	Sakamoto et al. ....	370/338	OTHER PUBLICATIONS			
5,903,595 A	5/1999	Suzuki .....	375/207	Al-Ahmad, H.A.M. et al., "Doppler Frequency Correction for a Non-Geostationary Communications Satellite. Techniques for CERS and T-SAT," <i>Electronics Division Colloquium on Low Noise Oscillators and Synthesizer</i> , Jan. 23, 1986, pp. 4/1-4/5.			
5,903,609 A	5/1999	Kool et al. ....	375/261				
5,903,827 A	5/1999	Kennan et al. ....	455/326				
5,903,854 A	5/1999	Abe et al. ....	455/575				
5,905,449 A	5/1999	Tsubouchi et al. ....	340/925.69				
5,907,149 A	5/1999	Marckini .....	235/487				
5,907,197 A	5/1999	Faulk .....	307/119				

- Ali, I. et al., "Doppler Characterization for LEO Satellites," *IEEE Trans. On Communications*, vol. 46, No. 3, Mar. 1998, pp. 309–313.
- Allan, D.W., "Statistics of Atomic Frequency Standards," *Proc. Of the IEEE Special Issue on Frequency Stability*, Feb. 1966, pp. 221–230.
- Allstot, D.J. et al., "MOS Switched Capacitor Ladder Filters," *IEEE Journal of Solid-State Circuits*, vol. SC-13, No. 6, Dec. 1978, pp. 806–814.
- Allstot, D.J. and Black Jr. W.C., "Technological Design Considerations for Monolithic MOS Switched-Capacitor Filtering Systems," *Proceedings of the IEEE*, vol. 71, No. 8, Aug. 1983, pp. 967–986.
- Alouini, M. et al., "Channel Characterization and Modeling for Ka-Band Very Small Aperture Terminals," *Proc. Of the IEEE*, vol. 85, No. 6, Jun. 1997, pp. 981–997.
- Andreyev, G.A. and Ogarev, S.A., "Phase Distortions of Keyed Millimeter-Wave Signals in the Case of Propagation in a Turbulent Atmosphere," *Telecommunications and Radio Engineering*, vol. 43, No. 12, Dec. 1988, pp. 87–90.
- Antonetti, A. et al., "Optoelectronic Sampling in the Pico-second Range," *Optics Communications*, vol. 21, No. 2, May 1977, pp. 211–214.
- Austin, J. et al., "Doppler Correction of the Telecommunication Payload Oscillators in the UK T-SAT," *18<sup>th</sup> European Microwave Conference*, Sep. 12–15, 1988, pp. 851–857.
- Auston, D.H., "Picosecond optoelectronic switching and gating in silicon," *Applied Physics Letters*, vol. 26, No. 3, Feb. 1, 1975, pp. 101–103.
- Baher, H., "Transfer Functions for Switched-Capacitor and Wave Digital Filters," *IEEE Transactions on Circuits and Systems*, vol. CAS-33, No. 11, Nov. 1986, pp. 1138–1142.
- Baines, R., "The DSP Bottleneck," *IEEE Communications Magazine*, May 1995, pp. 46–54.
- Banjo, O.P. and Vilar, E., "Binary Error Probabilities on Earth-Space Links Subject to Scintillation Fading," *Electronics Letters*, vol. 21, No. 7, Mar. 28, 1985, pp. 296–297.
- Banjo, O.P. and Vilar, E., "The Dependence of Slant Path Amplitude Scintillations on Various Meteorological Parameters," *Antennas and Propagation (ICAP 87) Part 2: Propagation*, Mar. 30–Apr. 2, 1987, pp. 277–280.
- Banjo, O.P. and Vilar, E., "Measurement and Modeling of Amplitude Scintillations on Low-Elevation Earth-Space Paths and Impact on Communication Systems," *IEEE Trans. On Communications*, vol. COM-34, No. 8, Aug. 1986, pp. 774–780.
- Banjo, O.P. et al., "Tropospheric Amplitude Spectra Due to Absorption and Scattering in Earth-Space Paths," *Antennas and Propagation (ICAP 85)*, Apr. 16–19, 1985, pp. 77–82.
- Basili, P. et al., "Case Study of Intense Scintillation Events on the OTS Path," *IEEE Trans. On Antennas and Propagation*, vol. 38, No. 1, Jan. 1990, pp. 107–113.
- Basili, P. et al., "Observation of High C<sup>2</sup> and Turbulent Path Length on OTS Space-Earth Link," *Electronics Letters*, vol. 24, No. 17, Aug. 18, 1988, pp. 1114–1116.
- Blakey, J.R. et al., "Measurement of Atmospheric Millimetre-Wave Phase Scintillations in an Absorption Region," *Electronics Letters*, vol. 21, No. 11, May 23, 1985, pp. 486–487.
- Burgueño, A. et al., "Influence of rain gauge integration time on the rain rate statistics used in microwave communications," *Annales des Telecommunications*, Sep./Oct. 1988, pp. 522–527.
- Burgueño, A. et al., "Long-Term Joint Statistical Analysis of Duration and Intensity of Rainfall Rate with Application to Microwave Communications," *Antennas and Propagation (ICAP 87) Part 2: Propagation*, Mar. 30–Apr. 2, 1987, pp. 198–201.
- Burgueño, A. et al., "Long Term Statistics of Precipitation Rate Return Periods in the Context of Microwave Communications," *Antennas and Propagation (ICAP 89) Part 2: Propagation*, Apr. 4–7, 1989, pp. 297–301.
- Burgueño, A. et al., "Spectral Analysis of 49 Years of Rainfall Rate and Relation to Fade Dynamics," *IEEE Trans. On Communications*, vol. 38, No. 9, Sep. 1990, pp. 1359–1366.
- Catalan, C. and Vilar, E., "Approach for satellite slant path remote sensing," *Electronics Letters*, vol. 34, No. 12, Jun. 11, 1998, pp. 1238–1240.
- Chan, P. et al., "A Highly Linear 1-GHz CMOS Downconversion Mixer," *European Solid State Circuits Conference*, Seville, Spain, Sep. 22–24, 1993, pp. 210–213.
- Copy of Declaration of Michael J. Bultman filed in patent application Ser. No. 09/176,022, which is directed to related subject matter.
- Copy of Declaration of Robert W. Cook filed in patent application Ser. No. 09/176,022, which is directed to related subject matter.
- Copy of Declaration of Alex Holtz filed in patent application Ser. No. 09/176,022, which is directed to related subject matter.
- Copy of Declaration of Richard C. Looke filed in patent application Ser. No. 09/176,022, which is directed to related subject matter.
- Copy of Declaration of Charley D. Moses, Jr. filed in patent application Ser. No. 09/176,022, which is directed to related subject matter.
- Copy of Declaration of Jeffrey L. Parker and David F. Sorrells, with attachment Exhibit 1, filed in patent application Ser. No. 09/176,022, which is directed to related subject matter.
- Dewey, R.J. and Collier, C.J., "Multi-Mode Radio Receiver," pp. 3/1–3/5.
- Dialog File 347 (JAPIO) English Language Patent Abstract for JP 2-276351, published Nov. 13, 1990, (1 page).
- Dialog File 347 (JAPIO) English Language Patent Abstract for JP 2-131629, published May 21, 1990, (1 page).
- Dialog File 347 (JAPIO) English Language Patent Abstract for JP 2-39632, published Feb. 8, 1990, (1 page).
- Dialog File 348 (European Patents) English Language Patent Abstract for EP 0 785 635 A1, published Dec. 26, 1996, (3 pages).
- Dialog File 348 (European Patents) English Language Patent Abstract for EP 35166 A1, published Feb. 18, 1981, (2 pages).
- "DSO takes sampling rate to 1 Ghz," *Electronic Engineering*, Mar. 1987, pp. 77 and 79.
- Erdi, G. and Henneuse, P.R., "A Precision FET-Less Sample-and-Hold with High Charge-to-Droop Current Ratio," *IEEE Journal of Solid-State Circuits*, vol. SC-13, No. 6, Dec. 1978, pp. 864–873.
- Faulkner, N.D. and Vilar, E., "Subharmonic Sampling for the Measurement of Short Term Stability of Microwave Oscillators," *IEEE Trans. On Instrumentation and Measurement*, vol. IM-32, No. 1, Mar. 1983, pp. 208–213.

- Faulkner, N.D. et al., "Sub-Harmonic Sampling for the Accurate Measurement of Frequency Stability of Microwave Oscillators," *CPEM 82 Digest: Conf. On Precision Electromagnetic Measurements*, 1982, pp. M-10 & M-11.
- Faulkner, N.D. and Vilar, E., "Time Domain Analysis of Frequency Stability Using Non-Zero Dead-Time Counter Techniques," *CPEM 84 Digest Conf. On Precision Electromagnetic Measurements*, 1984, pp. 81-82.
- Filip, M. and Vilar, E., "Optimum Utilization of the Channel Capacity of a Satellite Link in the Presence of Amplitude Scintillations and Rain Attenuation," *IEEE Trans. On Communications*, vol. 38, No. 11, Nov. 1990, pp. 1958-1965.
- Fukahori, K., "A CMOS Narrow-Band Signaling Filter with Q Reduction," *IEEE Journal of Solid-State Circuits*, vol. SC-19, No. 6, Dec. 1984, pp. 926-932.
- Fukuchi, H. and Otsu, Y., "Available time statistics of rain attenuation on earth-space path," *IEE Proc.*, vol. 135, pt. H, No. 6, Dec. 1988, pp. 387-390.
- Gibbins, C.J. and Chadha, R., "Millimetre-wave propagation through hydrocarbon flame," *IEE Proc.*, vol. 134, pt. H, No. 2, Apr. 1987, pp. 169-173.
- Gilchrist, B. et al., "Sampling hikes performance of frequency synthesizers," *Microwaves R&F*, Jan. 1984, pp. 93-94 and 110.
- Gossard, E.E., "Clear weather meteorological effects on propagation at frequencies above 1 Ghz," *Radio Science*, vol. 16, No. 5, Sep.-Oct. 1981, pp. 589-608.
- Gregorian, R. et al., "Switched-Capacitor Circuit Design," *Proceedings of the IEEE*, vol. 71, No. 8, Aug. 1983, pp. 941-966.
- Groshong et al., "Undersampling Techniques Simplify Digital Radio," *Electronic Design*, May 23, 1991, pp. 67-68, 70, 73-75 and 78.
- Grove, W.M., "Sampling for Oscilloscopes and Other RF Systems: Dc through X-Band," *IEEE Trans. On Microwave Theory and Techniques*, Dec. 1966, pp. 629-635.
- Haddon, J. et al., "Measurement of Microwave Scintillations on a Satellite Down-Line at X-Band," *2<sup>nd</sup> Int'l Conf. On Antennas and Propagation Part 2: Propagation*, Apr. 13-16, 1991, pp. 113-117.
- Haddon, J. and Vilar, E., "Scattering Induced Microwave Scintillations from Clear Air and Rain on Earth Space Paths and the Influence of Antenna Aperture," *IEEE Trans. On Antennas and Propagation*, vol. AP-34, No. 5, May 1986, pp. 646-657.
- Hafdallah, H. et al., "2-4 Ghz MESFET Sampler," *Electronics Letters*, vol. 24, No. 3, Feb. 4, 1988, pp. 151-153.
- Herben, M.H.A.J., "Amplitude and Phase Scintillation Measurements on 8-2 km Line-Of-Sight Path at 30 Ghz," *Electronics Letters*, vol. 18, No. 7, Apr. 1, 1982, pp. 287-289.
- Hewitt, A. et al., "An 18 Ghz Wideband LOS Multipath Experiment," *Int'l Conf. On Measurements for Telecommunication Transmission Systems-MTTS 85*, Nov. 27-28, 1985, pp. 112-116.
- Hewitt, A. et al., "An Autoregressive Approach to the Identification of Multipath Ray Parameters from Field Measurements," *IEEE Trans. On Communications*, vol. 37, No. 11, Nov. 1989, pp. 1136-1143.
- Hewitt, A. and Vilar, E., "Selective fading on LOS Microwave Links: Classical and Spread-Spectrum Measurement Techniques," *IEEE Trans. On Communications*, vol. 36, No. 7, Jul. 1988, pp. 789-796.
- Hospitalier, E., "Instruments for Recording and Observing Rapidly Varying Phenomena," *Science Abstracts*, vol. VII, 1904, pp. 22-23.
- Howard, I.M. and Swansson, N.S., "Demodulating High Frequency Resonance Signals for Bearing Fault Detection," *The Institution of Engineers Australia Communications Conference*, Melbourne Sep. 18-20, 1990, pp. 115-121.
- Hu, X., *A Switched-Current Sample-and-Hold Amplifier for FM Demodulation*, Thesis for Master of Applied Science, Dept. of Electrical and Computer Engineering, University of Toronto, 1995, pp. 1-64.
- Hung, H-L. A. et al., "Characterization of Microwave Integrated Circuits Using An Optical Phase-Locking and Sampling System," *IEEE MIT-S Digest*, 1991, pp. 507-510.
- Hurst, P.J., "Shifting the Frequency Response of Switched-Capacitor Filters by Nonuniform Sampling," *IEEE Transactions on Circuits and Systems*, vol. 38, No. 1, Jan. 1991, pp. 12-19.
- Itakura, T., "Effects of the sampling pulse width on the frequency characteristics of a sample-and-hold circuit," *IEEE Proc. Circuits, Devices and Systems*, vol. 141, No. 4, Aug. 1994, pp. 328-336.
- Janssen, J.M.L., "An Experimental 'Stroboscopic' Oscilloscope for Frequencies up to about 50 Mc/s: I. Fundamentals," *Philips Technical Review*, vol. 12, No. 2, Aug. 1950, pp. 52-59.
- Janssen, J.M.L. Michels, A.J., "An Experimental 'Stroboscopic' Oscilloscope for Frequencies up to about 50 Mc/s: II. Electrical Build-Up," *Philips Technical Review*, vol. 12, No. 3, Sep. 1950, pp. 73-82.
- Jondral, V.F. et al., "Doppler Profiles for Communication Satellites," *Frequenz*, May-Jun. 1996, pp. 111-116.
- Kaleh, G.K., "A Frequency Diversity Spread Spectrum System for Communication in the Presence of In-band Interference," *1995 IEEE Globecom*, pp. 66-70.
- Karasawa, Y. et al., "A New Prediction Method for Tropospheric Scintillation on Earth-Space Paths," *IEEE Trans. On Antennas and Propagation*, vol. 36, No. 11, Nov. 1988, pp. 1608-1614.
- Kirsten, J. and Fleming, J., "Undersampling reduces data-acquisition costs for select applications," *EDN*, Jun. 21, 1990, pp. 217-222, 226-228.
- Lam, W.K. et al., "Measurement of the Phase Noise Characteristics of an Unlocked Communications Channel Identifier," *Proc. Of the 1993 IEEE International Frequency Control Symposium*, Jun. 2-4, 1993, pp. 283-288.
- Lam, W.K. et al., "Wideband sounding of 11.6 Ghz transhorizon channel," *Electronics Letters*, vol. 30, No. 9, Apr. 28, 1994, pp. 738-739.
- Larkin, K.G., "Efficient demodulator for bandpass sampled AM signals," *Electronics Letters*, vol. 32, No. 2, Jan. 18, 1996, pp. 101-102.
- Lau, W.H. et al., "Analysis of the Time Variant Structure of Microwave Line-of-sight Multipath Phenomena," *IEEE Global Telecommunications Conference & Exhibition*, Nov. 28-Dec. 1, 1988, pp. 1707-1711.
- Lau, W.H. et al., "Improved Prony Algorithm to Identify Multipath Components," *Electronics Letters*, vol. 23, No. 20, Sep. 24, 1987, pp. 1059-1060.
- Lesage, P. and Audoin, C., "Effect of Dead-Time on the Estimation of the Two-Sample Variance," *IEEE trans. On Instrumentation and Measurement*, vol. IM-28, No. 1, Mar. 1979, pp. 6-10.

- Liechti, C.A., "Performance of Dual-gate GaAs MESFET's as Gain-Controlled Low-Noise Amplifiers and High-Speed Modulators," *IEEE Trans. On Microwave Theory and Techniques*, vol. MTT-23, No. 6, Jun. 1975, pp. 461-469.
- Linnenbrink, T.E. et al., "A One Gigasample Per Second Transient Recorder," *IEEE trans. On Nuclear Science*, vol. NS-26, No. 4, Aug. 1979, pp. 4443-4449.
- Liou, M.L., "A Tutorial on Computer-Aided Analysis of Switched-Capacitor Circuits," *Proceedings of the IEEE*, vol. 71, No. 8, Aug. 1983, pp. 987-1005.
- Lo, P. et al., "Coherent Automatic Gain Control," *IEE Colloquium on Phase Locked Techniques*, Mar. 26, 1980, pp. 2/1-2/6.
- Lo, P. et al., "Computation of Rain Induced Scintillations on Satellite Down-Links at Microwave Frequencies," *Third Int'l Conf. On Antennas and Propagation (ICAP 83) Part 2: Propagation*, Apr. 12-15, 1983, pp. 127-131.
- Lo, P.S.L.O. et al., "Observations of Amplitude Scintillations on a Low-Elevation Earth-Space Path," *Electronics Letters*, vol. 20, No. 7, Mar. 29, 1984, pp. 307-308.
- Madani, K. and Aithison, C.S., "A 20 Ghz Microwave Sampler," *IEEE Trans. On Microwave Theory and Techniques*, vol. 40, No. 10, Oct. 1992, pp. 1960-1963.
- Marsland, R.A. et al., "130 Ghz GaAs monolithic integrated circuit sampling head," *Appl. Phys. Lett.*, vol. 55, No. 6, Aug. 7, 1989, pp. 592-594.
- Martin, K. and Sedra, A.S., "Switched-Capacitor Building Blocks for Adaptive Systems," *IEEE Transactions on Circuits and Systems*, vol. CAS-28, No. 6, Jun. 1981, pp. 576-584.
- Marzano, F.S. and d'Auria, G., "Model-based Prediction of Amplitude Scintillation variance due to Clear-Air Tropospheric Turbulence on Earth-Satellite Microwave Links," *IEEE Trans. On Antennas and Propagation*, vol. 46, No. 10, Oct. 1998, pp. 1506-1518.
- Matricciani, E., "Prediction of fade durations due to rain in satellite communication systems," *Radio Science*, vol. 32, No. 3, May-Jun. 1997, pp. 935-941.
- McQueen, J.G., "The Monitoring of High-Speed Waveforms," *Electronic Engineering*, Oct. 1952, pp. 436-441.
- Merkelo, J. and Hall, R.D., "Broad-Band Thin-Film Signal Sampler," *IEEE Journal of Solid-State Circuits*, vol. SC-7, No. 1, Feb. 1972, pp. 50-54.
- Merlo, U. et al., "Amplitude Scintillation Cycles in a Sirio Satellite-Earth Link," *Electronics Letters*, vol. 21, No. 23, Nov. 7, 1985, pp. 1094-1096.
- Morris, D., "Radio-holographic reflector measurement of the 30-m millimeter radio telescope at 22 Ghz with a cosmic signal source," *Astronomy and Astrophysics*, vol. 203, No. 2, Sep. (II) 1988, pp. 399-406.
- Moulsley, T.J. et al., "The efficient acquisition and processing of propagation statistics," *Journal of the Institution of Electronic and Radio Engineers*, vol. 55, No. 3, Mar. 1985, pp. 97-103.
- Ndzi, D. et al., "Wide-Band Statistical Characterization of an Over-the-Sea Experimental Transhorizon Link," *IEE Colloquium on Radio Communications at Microwave and Millimetre Wave Frequencies*, Dec. 16, 1996, pp. 1/1-1/6.
- Ndzi, D. et al., "Wideband Statistics of Signal Levels and Doppler Spread on an Over-The-Sea Transhorizon Link," *IEE Colloquium on Propagation Characteristics and Related System Techniques for Beyond Line-of-Sight Radio*, Nov. 24, 1997, pp. 9/1-9/6.
- "New zero IF chipset from Philips," *Electronic Engineering*, Sep. 1995, p. 10.
- Ohara, H. et al., "First monolithic PCM filter cuts cost of telecomm systems," *Electronic Design*, vol. 27, No. 8, Apr. 12, 1979, (6 pages).
- Oppenheim, A.V. et al., *Signals and Systems*, Prentice-Hall, 1983, pp. 527-531 and 561-562.
- Ortgies, G., "Experimental Parameters Affecting Amplitude Scintillation Measurements on Satellite Links," *Electronics Letters*, vol. 21, No. 17, Aug. 15, 1985, pp. 771-772.
- Pärssinen et al., "A 2-GHz Subharmonic Sampler for Signal Downconversion," *IEEE Trans. on Microwave Theory and Techniques*, vol. 45, No. 12, Dec. 1997, (7 pages).
- Peeters, G. et al., "Evaluation of Statistical Models for Clear-Air Scintillation Prediction Using Olympus Satellite Measurements," *International Journal of Satellite Communications*, vol. 15, No. 2, Mar.-Apr. 1997, pp. 73-88.
- Perrey, A.G. and Schoenwetter, H.K., *NBS Technical Note 1121: A Schottky Diode Bridge Sampling Gate*, May 1980, pp. 1-14.
- Poulton, K. et al., "A 1-Ghz 6-bit ADC System," *IEEE Journal of Solid-State Circuits*, vol. SC-22, No. 6, Dec. 1987, pp. 962-969.
- Press Release, "Parkervision, Inc. Announces Fiscal 1993 Results," 2 pages, Apr. 6, 1994.
- Press Release, "Parkervision, Inc. Announces the Appointment of Michael Baker to the New Position of National Sales Manager," 1 page, Apr. 7, 1994.
- Press Release, "Parkervision's Cameraman Well-Received By Distance Learning Market," 2 pages, Apr. 8, 1994.
- Press Release, "Parkervision, Inc. Announces First Quarter Financial Results," 2 pages, Apr. 26, 1994.
- Press Release, "Parkervision, Inc. Announces The Retirement of William H. Fletcher, Chief Financial Officer," 1 page, May 11, 1994.
- Press Release, "Parkervision, Inc. Announces New Cameraman System 11™ At Infocomm Trade Show," 3 pages, Jun. 9, 1994.
- Press Release, "Parkervision, Inc. Announces Appointments to its National Sales Force," 2 pages, Jun. 17, 1994.
- Press Release, "Parkervision, Inc. Announces Second Quarter and Six Months Financial Results," 3 pages, Aug. 9, 1994.
- Press Release, "Parkervision, Inc. Announces Third Quarter and Nine Months Financial Results," 3 pages, Oct. 28, 1994.
- Press Release, "Parkervision, Inc. Announces First Significant Dealer Sale of Its Cameraman® System II," 2 pages, Nov. 7, 1994.
- Press Release, "Parkervision, Inc. Announces Fourth Quarter and Year End Results," 2 pages, Mar. 1, 1995.
- Press Release, "Parkervision, Inc. Announces Joint Product Developments With VTEL," 2 pages, Mar. 21, 1995.
- Press Release, "Parkervision, Inc. Announces First Quarter Financial Results," 3 pages, Apr. 28, 1995.
- Press Release, "Parkervision Wins Top 100 Product Districts' Choice Award," 1 page, Jun. 29, 1995.
- Press Release, "Parkervision National Sales Manager Next President of USDLA," 1 page, Jul. 6, 1995.
- Press Release, "Parkervision Granted New Patent," 1 page, Jul. 21, 1995.
- Press Release, "Parkervision, Inc. Announces Second Quarter and Six Months Financial Results," 2 pages, Jul. 31, 1995.

- Press Release, "Parkervision, Inc. Expands Its Cameraman System II Product Line," 2 pages, Sep. 22, 1995.
- Press Release, "Parkervision Announces New Camera Control Technology," 2 pages, Oct. 25, 1995.
- Press Release, "Parkervision, Inc. Announces Completion of VTEL/Parkervision Joint Product Line," 2 pages, Oct. 30, 1995.
- Press Release, "Parkervision, Inc. Announces Third Quarter and Nine Months Financial Results," 2 pages, Oct. 30, 1995.
- Press Release, "Parkervision's Cameraman Personal Locator Camera System Wins Telecon XV Award," 2 pages, Nov. 1, 1995.
- Press Release, "Parkervision, Inc. Announces Purchase Commitment From VTEL Corporation," 1 page, Feb. 26, 1996.
- Press Release, "ParkerVision, Inc. Announces Fourth Quarter and Year End Results," 2 pages, Feb. 27, 1996.
- Press Release, "ParkerVision, Inc. Expands its Product Line," 2 pages, Mar. 7, 1996.
- Press Release, "ParkerVision Files Patents for its Research of Wireless Technology," 1 page, Mar. 28, 1996.
- Press Release, "Parkervision, Inc. Announces First Significant Sale of Its Cameraman® Three-Chip System," 2 pages, Apr. 12, 1996.
- Press Release, "Parkervision, Inc. Introduces New Product Line For Studio Production Market," 2 pages, Apr. 15, 1996.
- Press Release, "Parkervision Inc. Announces Private Placement of 800,000 Shares," 1 page, Apr. 15, 1996.
- Press Release, "Parkervision, Inc. Announces First Quarter Financial Results," 3 pages, Apr. 30, 1996.
- Press Release, "ParkerVision's New Studio Product Wins Award," 2 pages, Jun. 5, 1996.
- Press Release, "Parkervision, Inc. Announces Second Quarter and Six Months Financial Results," 3 pages, Aug. 1, 1996.
- Press Release, "Parkervision, Inc. Announces Third Quarter and Nine Months Financial Results," 2 pages, Oct. 29, 1996.
- Press Release, "PictureTel and ParkerVision Sign Reseller Agreement," 2 pages, Oct. 30, 1996.
- Press Release, "CLI and ParkerVision Bring Enhanced Ease-of-Use to Videoconferencing," 2 pages, Jan. 20, 1997.
- Press Release, "Parkervision, Inc. Announces Fourth Quarter and Year End Results," 3 pages, Feb. 27, 1997.
- Press Release, "Parkervision, Inc. Announces First Quarter Financial Results," 3 pages, Apr. 29, 1997.
- Press Release, "NEC and Parkervision Make Distance Learning Closer," 2 pages, Jun. 18, 1997.
- Press Release, "Parkervision Supplies JPL with Robotic Cameras, Cameraman Shot Director for Mars Mission," 2 pages, Jul. 8, 1997.
- Press Release, "ParkerVision and IBM Join Forces to Create Wireless Computer Peripherals," 2 pages, Jul. 23, 1997.
- Press Release, "ParkerVision, Inc. Announces Second Quarter and Six Months Financial Results," 3 pages, Jul. 31, 1997.
- Press Release, "Parkervision, Inc. Announces Private Placement of 990,000 Shares," 2 pages, Sep. 8, 1997.
- Press Release, "Wal-Mart Chooses Parkervision for Broadcast Production," 2 pages, Oct. 24, 1997.
- Press Release, "Parkervision, Inc. Announces Third Quarter Financial Results," 3 pages, Oct. 30, 1997.
- Press Release, "ParkerVision Announces Breakthrough in Wireless Radio Frequency Technology," 3 pages, Dec. 10, 1997.
- Press Release, "Parkervision, Inc. Announces the Appointment of Joseph F. Skovron to the Position of Vice President, Licensing—Wireless Technologies," 2 pages, Jan. 9, 1998.
- Press Release, "Parkervision Announces Existing Agreement with IBM Terminates—Company Continues with Strategic Focus Announced in Dec.," 2 pages, Jan. 27, 1998.
- Press Release, "Laboratory Tests Verify Parkervision Wireless Technology," 2 pages, Mar. 3, 1998.
- Press Release, "Parkervision, Inc. Announces Fourth Quarter and Year End Financial Results," 3 pages, Mar. 5, 1998.
- Press Release, "Parkervision Awarded Editors' Pick of Show for NAB 98," 2 pages, Apr. 15, 1998.
- Press Release, "Parkervision Announces First Quarter Financial Results," 3 pages, May 4, 1998.
- Press Release, "Parkervision 'DIRECT2DATA' Introduced in Response to Market Demand," 3 pages, Jul. 9, 1998.
- Press Release, "Parkervision Expands Senior Management Team," 2 pages, Jul. 29, 1998.
- Press Release, "Parkervision Announces Second Quarter and Six Month Financial Results," 4 pages, Jul. 30, 1998.
- Press Release, "Parkervision Announces Third Quarter and Nine Month Financial Results," 3 pages, Oct. 30, 1998.
- Press Release, "Questar Infocomm, Inc. Invests \$5 Million in Parkervision Common Stock," 3 pages, Dec. 2, 1998.
- Press Release, "Parkervision Adds Two New Directors," 2 pages, Mar. 5, 1999.
- Press Release, "Parkervision Announces Fourth Quarter and Year End Financial Results," 3 pages, Mar. 5, 1999.
- Press Release, "Joint Marketing Agreement Offers New Automated Production Solution," 2 pages, Apr. 13, 1999.
- "Project COST 205: Scintillations in Earth-satellite links," *Alta Frequenza: Scientific Review in Electronics*, vol. LIV, No. 3, May-Jun., 1985, pp. 209-211.
- Razavi, B., *RF Microelectronics*, Prentice-Hall, 1998, pp. 147-149.
- Reeves, R.J.D., "The Recording and Collocation of Waveforms (Part 1)," *Electronic Engineering*, Mar. 1959, pp. 130-137.
- Reeves, R.J.D., "The Recording and Collocation of Waveforms (Part 2)," *Electronic Engineering*, Apr. 1959, pp. 204-212.
- Rein, H.M. and Zahn, M., "Subnanosecond-Pulse Generator with Variable Pulsewidth Using Avalanche Transistors," *Electronics Letters*, vol. 11, No. 1, Jan. 9, 1975, pp. 21-23.
- Riad, S.M. and Nahman, N.S., "Modeling of the Feed-through Wideband (DC to 12.4 Ghz) Sampling-Head," *IEEE MTT-S International Microwave Symposium Digest*, Jun. 27-29, 1978, pp. 267-269.
- Rizzoli, V. et al., "Computer-Aided Noise Analysis of MESFET and HEMT Mixers," *IEEE Trans. On Microwave Theory and Techniques*, vol. 37, No. 9, Sep. 1989, pp. 1401-1410.
- Rowe, H.E., *Signals and Noise in Communication Systems*, D. Van Nostrand Company, Inc., Princeton, New Jersey, 1965, including, for example, Chapter V, Pulse Modulation Systems.
- Rücker, F. and Dintelmann, F., "Effect of Antenna Size on OTS Signal Scintillations and Their Seasonal Dependence," *Electronics Letters*, vol. 19, No. 24, Nov. 24, 1983, pp. 1032-1034.
- Russell, R. and Hoare, L., "Millimeter Wave Phase Locked Oscillators," *Military Microwaves '78 Conference Proceedings*, Oct. 25-27, 1978, pp. 238-242.



- Sabel, L.P., "A DSP Implementation of a Robust Flexible Receiver/Demultiplexer for Broadcast Data Satellite Communications," *The Institution of Engineers Australia Communications Conference*, Melbourne Oct. 16-18, 1990, pp. 218-225.
- Salous, S., "IF digital generation of FMCW waveforms for wideband channel characterization," *IEE Proceedings-I*, vol. 139, No. 3, Jun. 1992, pp. 281-288.
- "Sampling Loops Lock Sources to 23 Ghz," *Microwaves & RF*, Sep. 1990, p. 212.
- Sasikumar, M. et al., "Active Compensation in the Switched-Capacitor Biquad," *Proceedings of the IEEE*, vol. 71, No. 8, Aug. 1983, pp. 1008-1009.
- Saul, P.H., "A GaAs MESFET Sample and Hold Switch," *5<sup>th</sup> European Solid State Circuits Conference-ESSCIRC 79*, 1979, pp. 5-7.
- Shen, D.H. et al., "A 900-MHZ RF Front-End with Integrated Discrete-Time Filtering," *IEEE Journal of Solid State Circuits*, vol. 31, No. 12, Dec. 1996, pp. 1945-1954.
- Shen, X.D. and Vilar, E., "Anomalous transhorizon propagation and meteorological processes of a multilink path," *Radio Science*, vol. 30, No. 5, Sep.-Oct. 1995, pp. 1467-1479.
- Shen, X. and Tawfik, A.N., "Dynamic Behavior of Radio Channels Due to Trans-Horizon Propagation Mechanisms," *Electronics Letters*, vol. 29, No. 17, Aug. 1993, pp. 1582-1583.
- Shen, X. et al., "Modeling Enhanced Spherical Diffraction and Troposcattering on a Transhorizon Path with aid of the parabolic Equation and Ray Tracing Methods," *IEE Colloquium on Common modeling techniques for electromagnetic wave and acoustic wave propagation*, Mar. 8, 1996, pp. 4/1-4/7.
- Shen, X. and Vilar, E., "Path loss statistics and mechanisms of transhorizon propagation over a sea path," *Electronics Letters*, vol. 32, No. 3, Feb. 1, 1996, pp. 259-261.
- Shen, D. et al., "A 900 MHz Integrated Discrete-Time Filtering RF Front-End," *IEEE International Solid State Circuits Conference*, vol. 39, Feb. 1996, pp. 54-55 and 417.
- Spillard, C. et al., "X-Band Tropospheric Transhorizon Propagation Under Differing Meteorological Conditions," *Antennas and Propagation (ICAP 89) Part 2: Propagation*, Apr. 4-7, 1989, pp. 451-455.
- Stafford, K.R. et al., "A Complete Monolithic Sample/Hold Amplifier," *IEEE Journal of Solid-State Circuits*, vol. SC-9, No. 6, Dec. 1974, pp. 381-387.
- Staruk, W. Jr. et al., "Pushing HF Data Rates," *Defense Electronics*, May 1985, pp. 211, 213, 215, 217, 220 & 222.
- Stephenson, A.G., "Digitizing multiple RF signals requires an optimum sampling rate," *Electronics*, Mar. 27, 1972, pp. 106-110.
- Sugarman, R., "Sampling Oscilloscope for Statistically Varying Pulses," *The Review of Scientific Instruments*, vol. 28, No. 11, Nov. 1957, pp. 933-938.
- Sylvain, M., "Experimental probing of multipath microwave channels," *Radio Science*, vol. 24, No. 2, Mar.-Apr. 1989, pp. 160-178.
- Takano, T., "Novel GaAs Pet Phase Detector Operable To Ka Band," *IEEE MT-S Digest*, 1984, pp. 381-383.
- Tan, M.A., "Biquadratic Transconductance Switched-Capacitor Filters," *IEEE Transactions on Circuits and Systems-I: Fundamental Theory and Applications*, vol. 40, No. 4, Apr. 1993, pp. 272-275.
- Tanaka, K. et al., "Single Chip Multisystem AM Stereo Decoder IC," *IEEE Trans. On Consumer Electronics*, vol. CE-32, No. 3, Aug. 1986, pp. 482-496.
- Tawfik, A.N., "Amplitude, Duration and Predictability of Long Hop Trans-Horizon X-band Signals Over the Sea," *Electronics Letters*, vol. 28, No. 6, Mar. 12, 1992, pp. 571-572.
- Tawfik, A.N. and Vilar, E., "Correlation of Transhorizon Signal Level Strength with Localized Surface Meteorological Parameters," *8<sup>th</sup> International Conf. On Antennas and Propagation*, Mar. 30-Apr. 2, 1993, pp. 335-339.
- Tawfik, A.N. and Vilar, E., "Dynamic Structure of a Transhorizon Signal at X-band Over a Sea Path," *Antennas and Propagation (ICAP 89) Part 2: Propagation*, Apr. 4-7, 1989, pp. 446-450.
- Tawfik, A.N. and Vilar, E., "Statistics of Duration and Intensity of Path Loss in a Microwave Transhorizon Sea-Path," *Electronics Letters*, vol. 26, No. 7, Mar. 29, 1990, pp. 474-476.
- Tawfik, A.N. and Vilar, E., "X-Band Transhorizon Measurements of CW Transmissions Over the Sea-Part 1: Path Loss, Duration of Events, and Their Modeling," *IEEE Trans. On Antennas and Propagation*, vol. 41, No. 11, Nov. 1993, pp. 1491-1500.
- Temes, G.C. and Tsividis, T., "The Special Section on Switched-Capacitor Circuits," *Proceedings of the IEEE*, vol. 71, No. 8, Aug. 1983, pp. 915-916.
- Thomas, G.B., *Calculus and Analytic Geometry*, Third Edition, Addison-Wesley Publishing, 1960, pp. 119-133.
- Tomassetti, Q., "An Unusual Microwave Mixer," *16<sup>th</sup> European Microwave Conference*, Sep. 8-12, 1986, pp. 754-759.
- Tortoli, P. et al., "Bidirectional Doppler Signal Analysis Based on a Single RF Sampling Channel," *IEEE Trans. On Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 41, No. 1, Jan. 1984, pp. 1-3.
- Tsividis, Y. and Antognetti, P. (Ed.), *Design of MOS VLSI Circuits for Telecommunications*, p. 304.
- Tsividis, Y., "Principles of Operation and Analysis of Switched-Capacitor Circuits," *Proceedings of the IEEE*, vol. 71, No. 8, Aug. 1983, pp. 926-940.
- Tsurumi, H. and Maeda, T., "Design Study on a Direct Conversion Receiver Front-End for 280 MHz, 900 MHz, and 2.6 Ghz Band Radio Communication Systems," *41<sup>st</sup> IEEE Vehicular Technology Conference*, May 19-22, 1991, pp. 457-462.
- Valdamanis, J.A. et al., "Picosecond and Subpicosecond Optoelectronics for Measurements of Future High Speed Electronic Devices," *IEDM Technical Digest*, Dec. 5-7, 1983, pp. 597-600.
- van de Kamp, M.M.J.L., "Asymmetric signal level distribution due to tropospheric scintillation," *Electronics Letters*, vol. 34, No. 11, May 28, 1998, pp. 1145-1146.
- Vasseur, H. and Vanhoenacker, D., "Characterization of tropospheric turbulent layers from radiosonde data," *Electronics Letters*, vol. 34, No. 4, Feb. 19, 1998, pp. 318-319.
- Verdone, R., "Outage Probability Analysis for Short-Range Communication Systems at 60 Ghz in ATT Urban Environments," *IEEE Trans. On Vehicular Technology*, vol. 46, No. 4, Nov. 1997, pp. 1027-1039.
- Vierira-Ribeiro, S.A., *Single-IF DECT Receiver Architecture using a Quadrature Sub-Sampling Band-Pass Sigma-Delta Modulator*, Thesis for Degree of Master's of Engineering, Carleton University, Apr. 1995, pp. 1-180.

- Vilar, E. et al., "A Comprehensive/Selective MM-Wave Satellite Downlink Experiment on Fade Dynamics," *10<sup>th</sup> International Conf. On Antennas and Propagation*, Apr. 14–17, 1997, pp. 2.98–2.101.
- Vilar, E. et al., "A System to Measure LOS Atmospheric Transmittance at 19 Ghz," *Agard Conf. Proc. No. 346: Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation*, Oct. 4–7, 1983, pp. 8–1—8–16.
- Vilar, E. and Smith, H., "A Theoretical and Experimental Study of Angular Scintillations in Earth Space Paths," *IEEE Trans. On Antennas and Propagation*, vol. AP-34, No. 1, Jan. 1986, pp. 2–10.
- Vilar, E. et al., "A Wide Band Transhorizon Experiment at 11.6 Ghz," *8<sup>th</sup> International Conf. On Antennas and Propagation*, Mar. 30– Apr. 2, 1993, pp. 441–445.
- Vilar, E. and Matthews, P.A., "Amplitude Dependence of Frequency in Oscillators," *Electronics Letters*, vol. 8, No. 20, Oct. 5, 1972, pp. 509–511.
- Vilar, E. et al., "An Experimental mm-wave receiver system for measuring phase noise due to atmospheric turbulence," *Conf. Proc. 25<sup>th</sup> European Microwave Conference*, 1995, pp. 114–119.
- Vilar, E. and Burgueño, A., "Analysis and Modeling of Time Intervals Between Rain Rate Exceedances in the Context of Fade Dynamics," *IEEE Trans. On Communications*, vol. 39, No. 9, Sep. 1991, pp. 1306–1312.
- Vilar, E. et al., "Angle of Arrival Fluctuations in High and Low Elevation Earth Space Paths," *Antennas and Propagation (ICAP 85)*, Apr. 16–19, 1985, pp. 83–88.
- Vilar, E., "Antennas and Propagation: A Telecommunications Systems Subject," *Electronics Division Colloquium on Teaching Antennas and Propagation to Undergraduates*, Mar. 8, 1988, (6 pages).
- Vilar, E. et al., "CERS\*. Millimetre-Wave Beacon Package and Related Payload Doppler Correction Strategies," *Electronics Division Colloquium on CERS- Communications Engineering Research Satellite*, Apr. 10, 1984, pp. 10/1–10/10.
- Vilar, E. and Mousley, T.J., "Comment and Reply: Probability Density Function of Amplitude Scintillations," *Electronics Letters*, vol. 21, No. 14, Jul. 4, 1985, pp. 620–622.
- Vilar, E. et al., "Comparison of Rainfall Rate Duration Distributions for ILE-IFE and Barcelona," *Electronics Letters*, vol. 28, No. 20, Sep. 24, 1992, pp. 1922–1924.
- Vilar, E., "Depolarization and Field Transmittances in Indoor Communications," *Electronics Letters*, vol. 27, No. 9, Apr. 25, 1991, pp. 732–733.
- Vilar, E. and Larsen, J.R., "Elevation Dependence of Amplitude Scintillations on Low Elevation Earth Space Paths," *Antennas and Propagation (ICAP 89) Part 2: Propagation*, Apr. 4–7, 1989, pp. 150–154.
- Vilar, E. et al., "Experimental System and Measurements of Transhorizon Signal Levels at 11 Ghz," *18<sup>th</sup> European Microwave Conference*, Sep. 12–15, 1988, 429–435.
- Vilar, E. and Matthews, P.A., "Importance of Amplitude Scintillations in Millimetric Radio Links," *Conf. Proc. 4<sup>th</sup> European Microwave Conference*, Sep. 10–13, 1974, pp. 202–206.
- Vilar, E. and Haddon, J., "Measurement and Modeling of Scintillation Intensity to Estimate Turbulence Parameters in an Earth-Space Path," *IEEE Trans. On Antennas and Propagation*, vol. AP-32, No. 4, Apr. 1984, pp. 340–346.
- Vilar, E. and Matthews, P.A., "Measurement of Phase Fluctuations on Millimetric Radiowave Propagation," *Electronics Letters*, vol. 7, No. 18, Sep. 9, 1971, pp. 566–568.
- Vilar, E. and Wan, K.W., "Narrow and Wide Band Estimates of Field Strength for Indoor Communications in the Millimetre Band," *Electronics Division Colloquium on Radio-communications in the Range 30–60 Ghz*, Jan. 17, 1994, pp. 5/4–5/8.
- Vilar, E. and Faulkner, N.D., "Phase Noise and Frequency Stability Measurements. Numerical Techniques and Limitations," *Electronics Division Colloquium on Low Noise Oscillators and Synthesizer*, Jan. 23, 1986, (5 pages).
- Vilar, E. and Senin, S., "Propagation phase noise identified using 40 Ghz satellite downlink," *Electronics Letters*, vol. 33, No. 22, Oct. 23, 1997, pp. 1901–1902.
- Vilar, E. et al., "Scattering and Extinction: Dependence Upon Raindrop Size Distribution in Temperate (Barcelona) and Tropical (Belem) Regions," *10<sup>th</sup> International Conf. On Antennas and Propagation*, Apr. 14–17, 1997, pp. 2.230–2.233.
- Vilar, E. and Haddon, J., "Scintillation Modeling and Measurement—A Tool for Remote-Sensing Slant Paths," *Agard Conf. Proc. No. 332: Propagation Aspects of Frequency Sharing, Interference And System Diversity*, Oct. 18–22, 1982, pp. 27–1—17–13.
- Vilar, E., "Some Limitations on Digital Transmission Through Turbulent Atmosphere," *Int'l Conf. On Satellite Communication Systems Technology*, Apr. 7–10, 1975, pp. 169–187.
- Vilar, E. and Matthews, P.A., "Summary of Scintillation Observations in a 36 Ghz Link Across London," *Int'l Conf. On Antennas and Propagation Part 2: Propagation*, Nov. 28–30, 1978, pp. 36–40.
- Vilar, E. et al., "Wideband Characterization of Scattering Channels," *10<sup>th</sup> International Conf. On Antennas and Propagation*, Apr. 14–17, 1997, pp. 2.353–2.358.
- Vollmer, A., "Complete GPS Receiver Fits on Two Chips," *Electronic Design*, Jul. 6, 1998, pp. 50, 52, 54, 56.
- Voltage and Time Resolution in Digitizing Oscilloscopes: Application Note 348*, Hewlett Packard Nov. 1986, pp. 1–11.
- Wan, K.W. et al., "A Novel Approach to the Simultaneous Measurement of Phase and Amplitude Noises in Oscillator," *19<sup>th</sup> European Microwave Conference Proceedings*, Sep. 4–7, 1989, pp. 809–813.
- Wan, K.W. et al., "Extended Variances and Autoregressive/Moving Average Algorithm for the Measurement and Synthesis of Oscillator Phase Noise," *Proc. Of the 43<sup>rd</sup> Annual Symposium on Frequency Control*, 1989, pp. 331–335.
- Wan, K.W. et al., "Wideband Transhorizon Channel Sounder at 11 Ghz," *Electronics Division Colloquium on High Bit Rate UHF/SHF Channel Sounders—Technology and Measurement*, Dec. 3, 1993, pp. 3/1–3/5.
- Wang, H., "A 1–V Multigigahertz RF Mixer Core in 0.5– $\mu$ m CMOS," *IEEE* 1998, 3 pages.

Watson, A.W.D. et al., "Digital Conversion and Signal Processing for High Performance Communications Receivers," pp. 367-373.

Weast, R.C. et al. (Ed.), *Handbook of Mathematical Tables*, Second Edition, The Chemical Rubber Co., 1964, pp. 480-485.

Wiley, R.G., "Approximate FM Demodulation Using Zero Crossings," *IEEE Trans. On Communications*, vol. COM-29, No. 7, Jul. 1981, pp. 1061-1065.

Worthman, W., "Convergence . . . Again," *RF Design*, Mar. 1999, p. 102.

Young, I.A. and Hodges, D.A., "MOS Switched-Capacitor Analog Sampled-Data Direct-Form Recursive Filters," *IEEE Journal of Solid-State Circuits*, vol. SC-14, No. 6, Dec. 1979, pp. 1020-1033.

\* cited by examiner

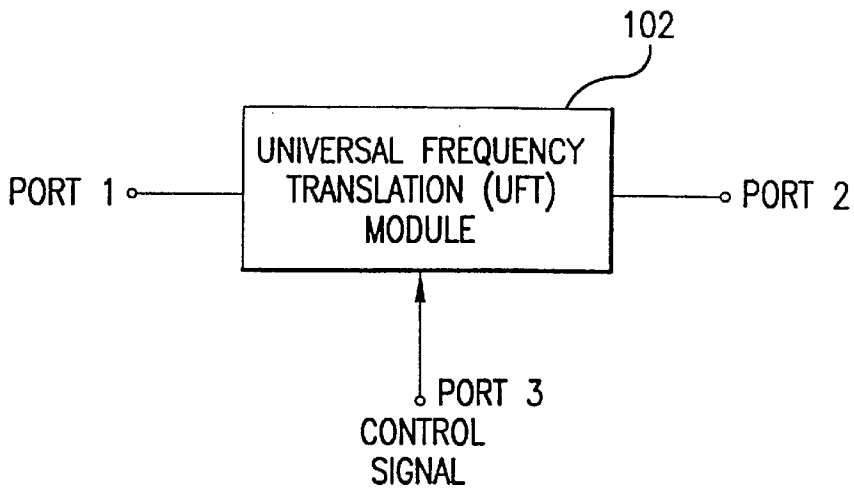


FIG. 1A

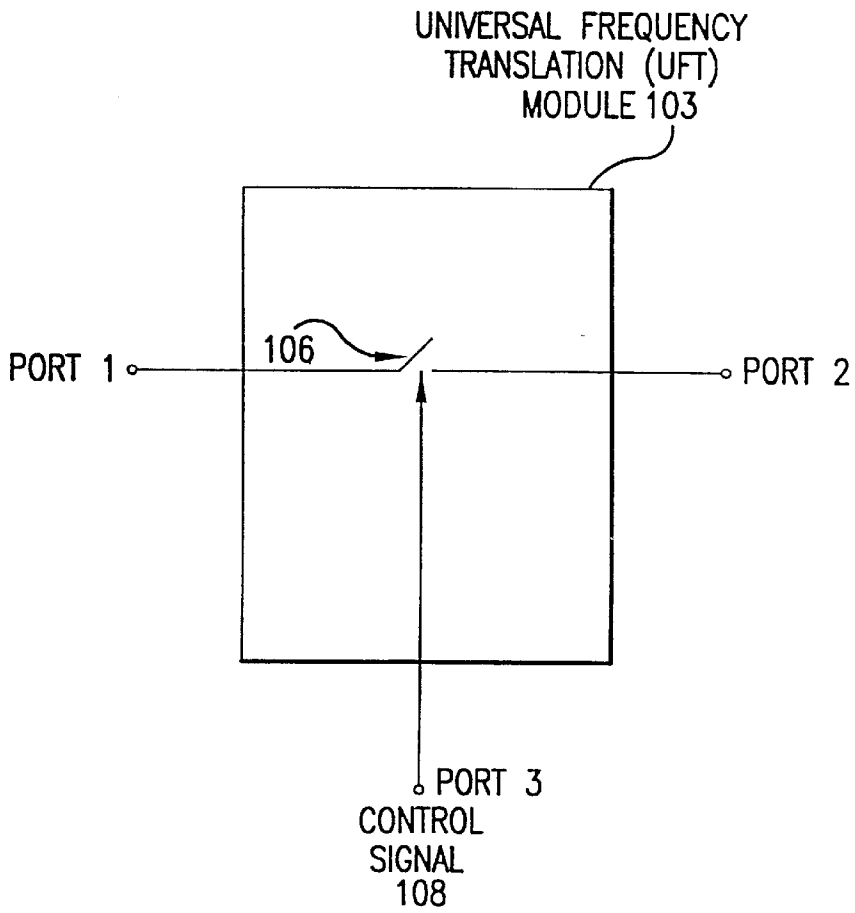


FIG. 1B

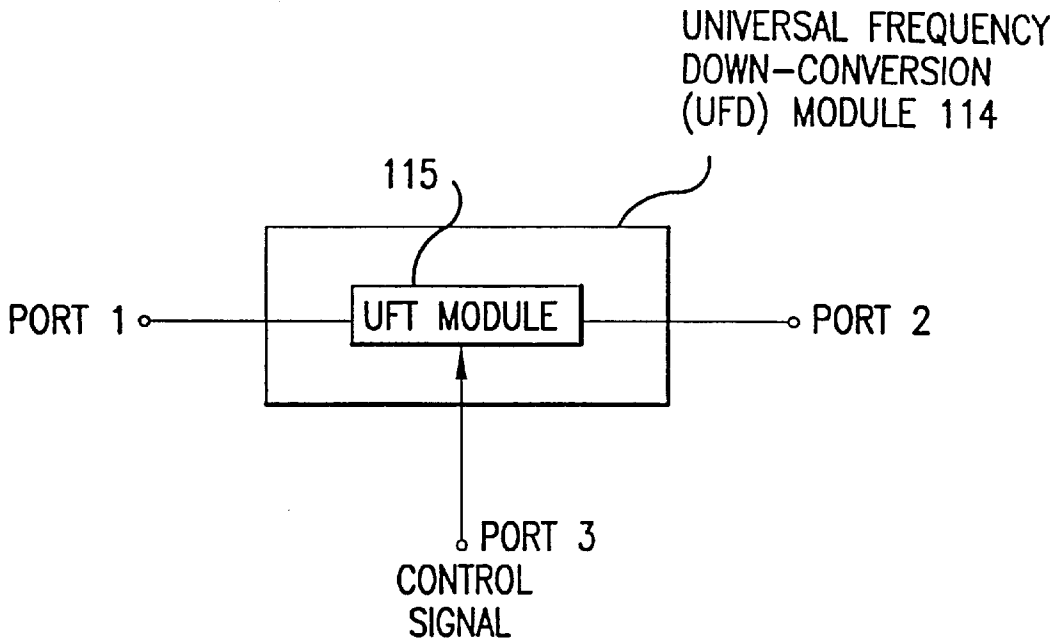


FIG. 1C

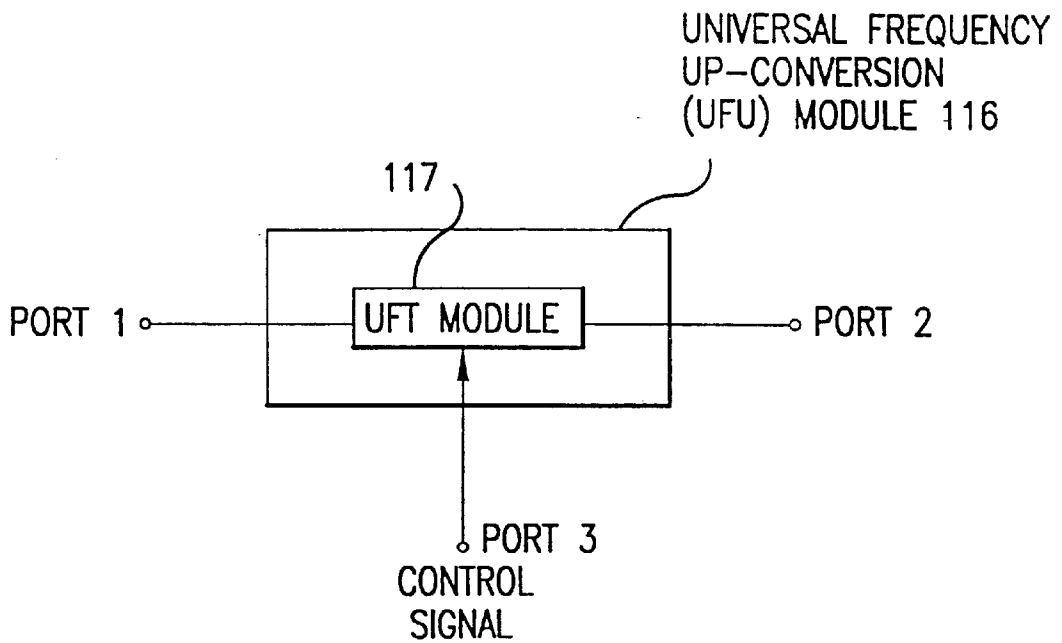


FIG. 1D

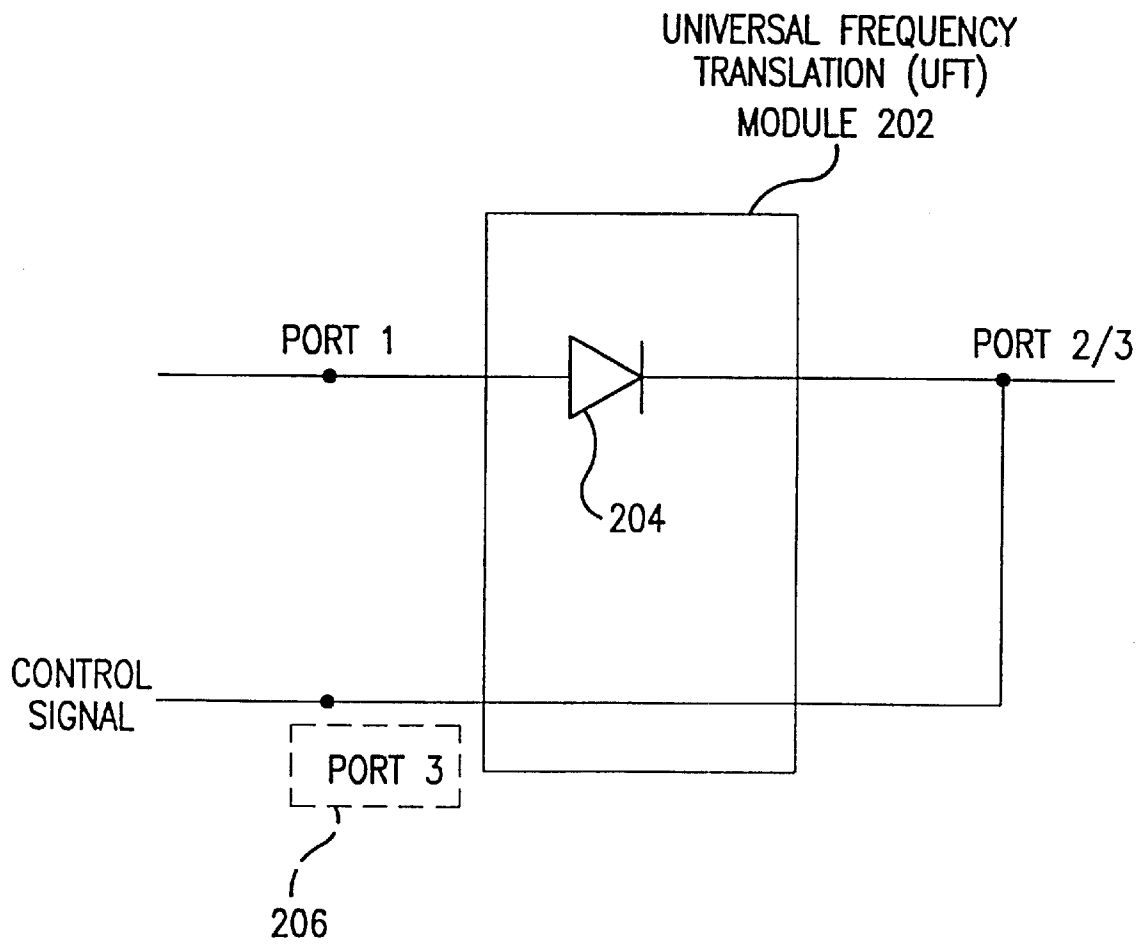


FIG. 2

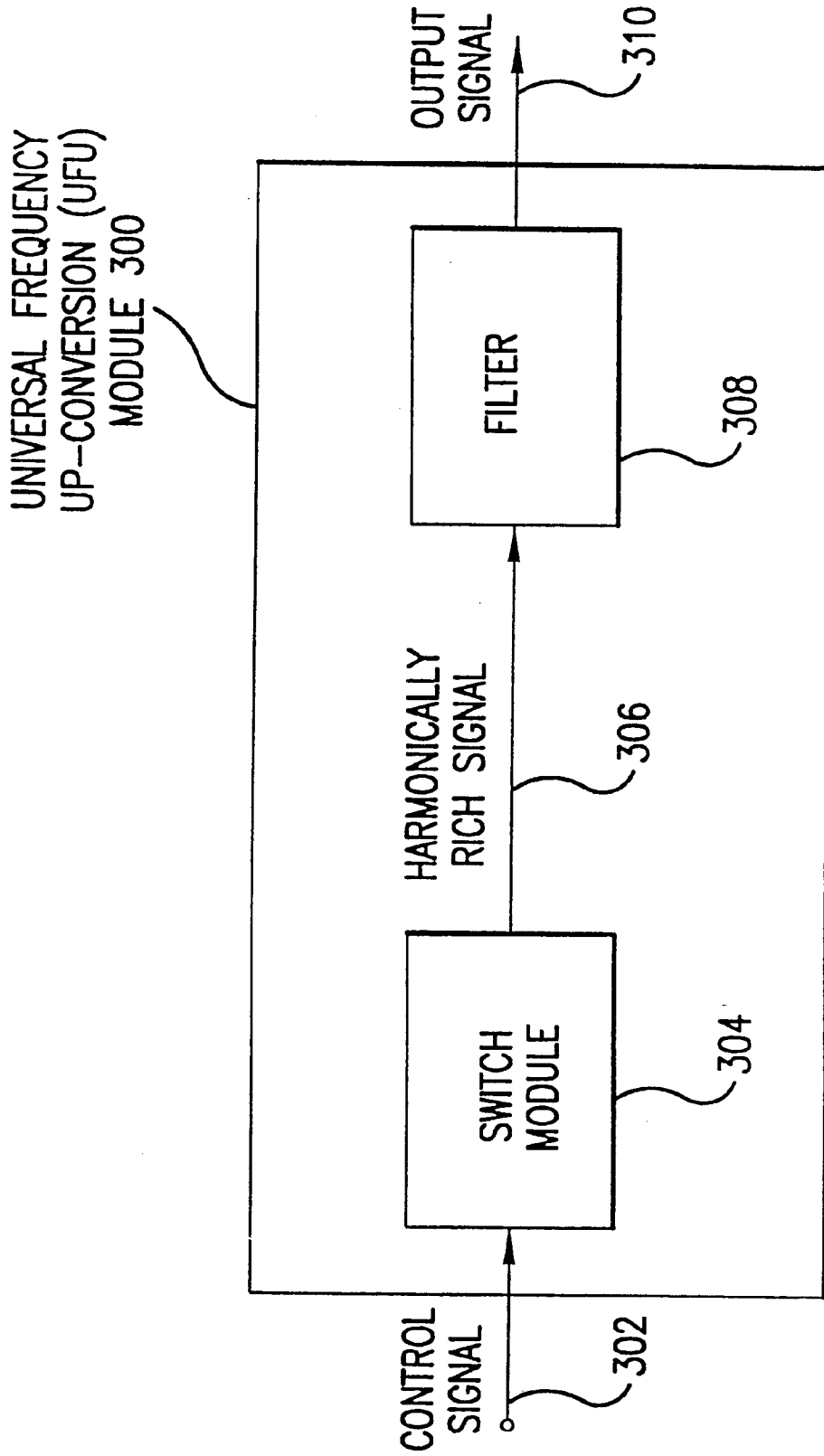
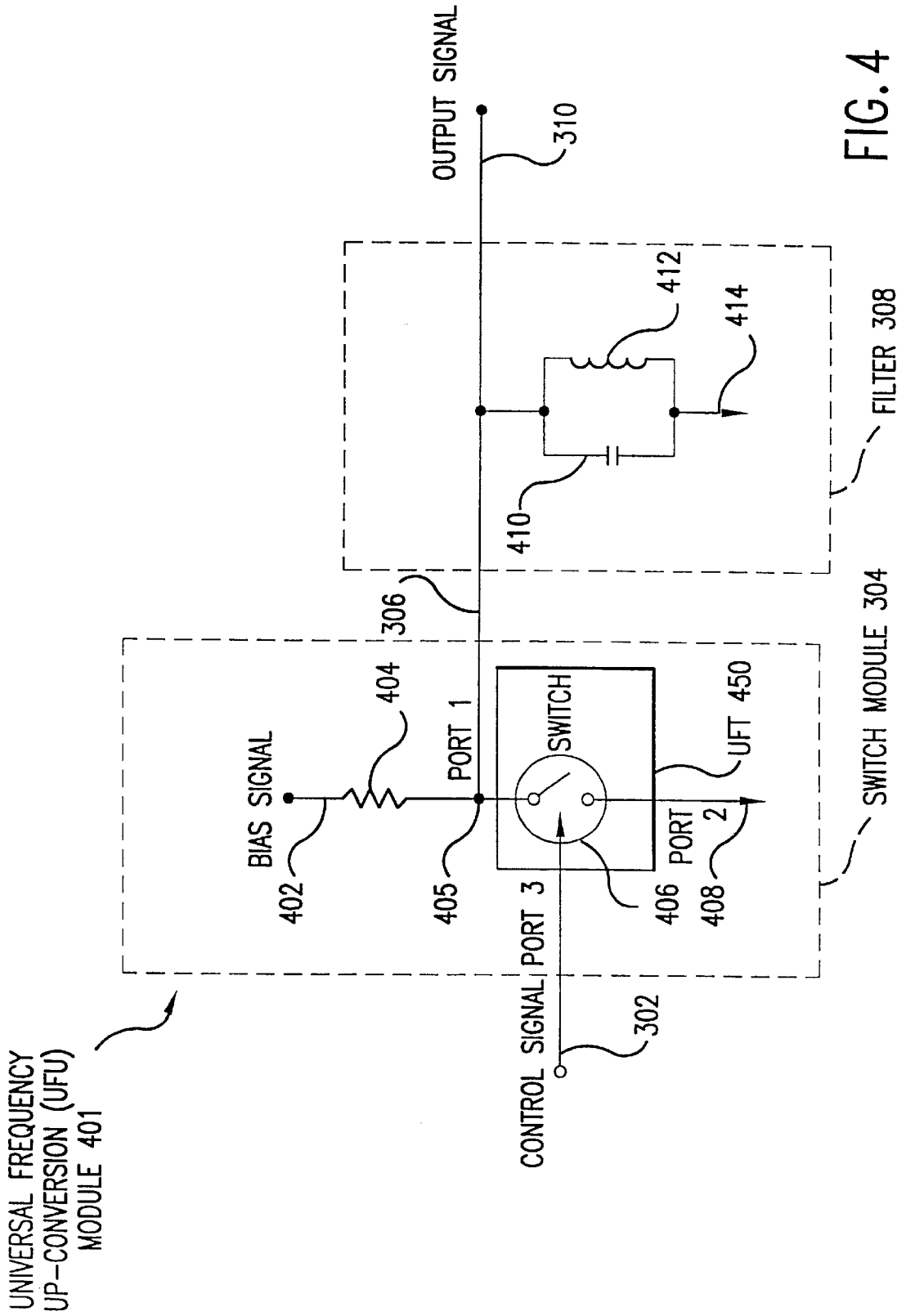


FIG. 3





UNIVERSAL FREQUENCY  
UP-CONVERSION  
(UFU) MODULE 590

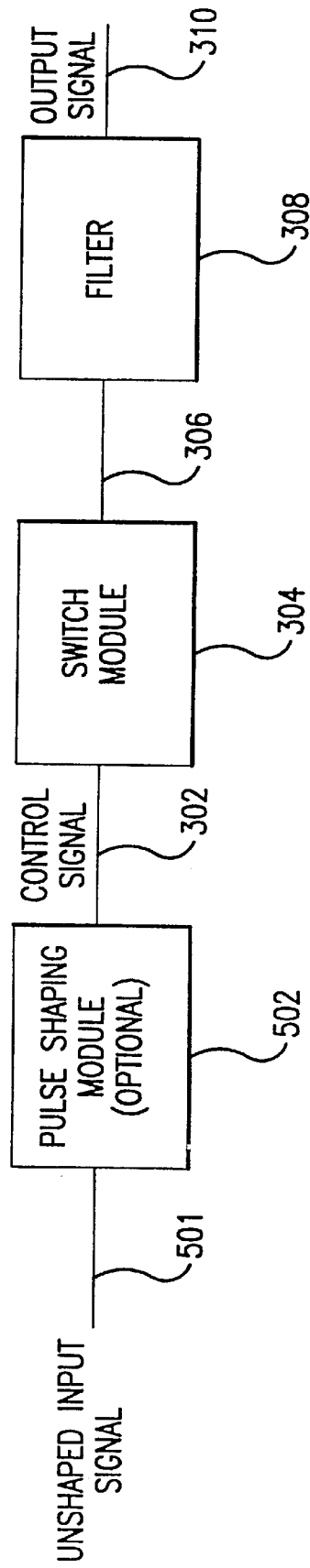


FIG. 5

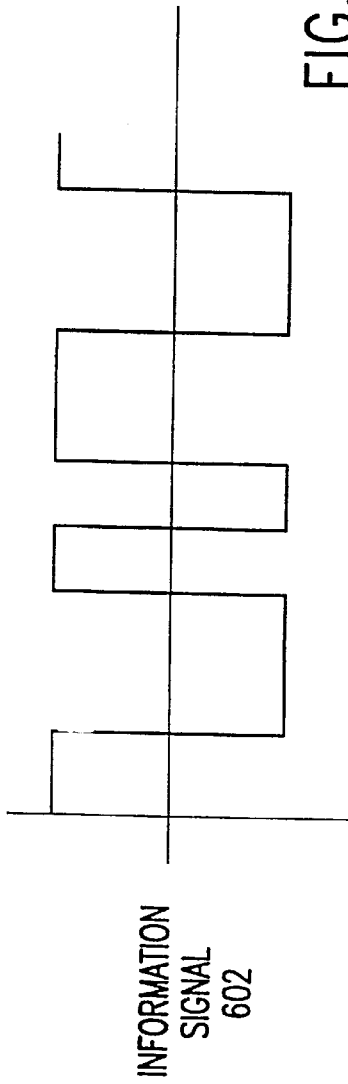


FIG. 6A

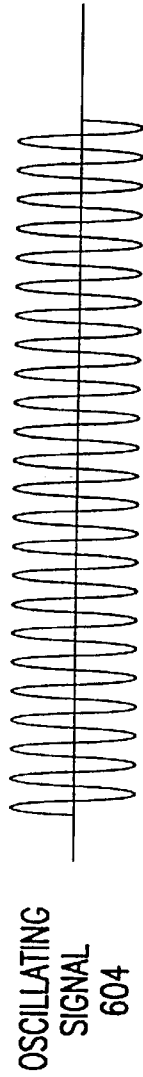


FIG. 6B

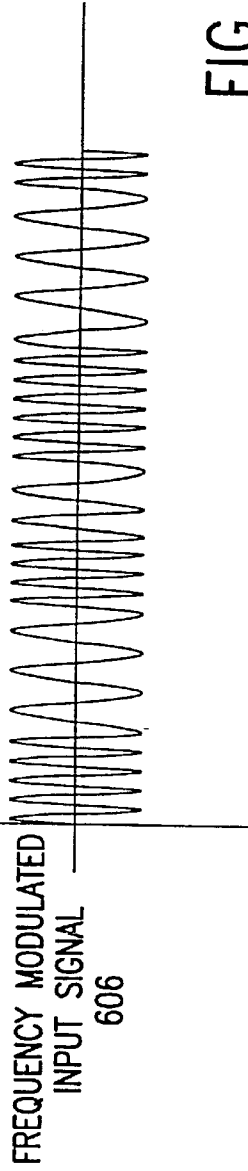


FIG. 6C

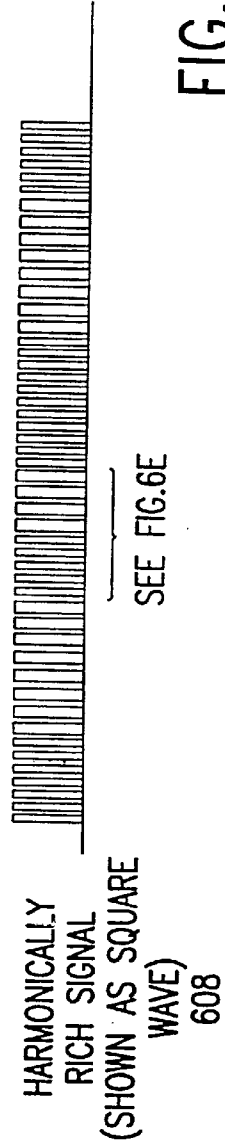
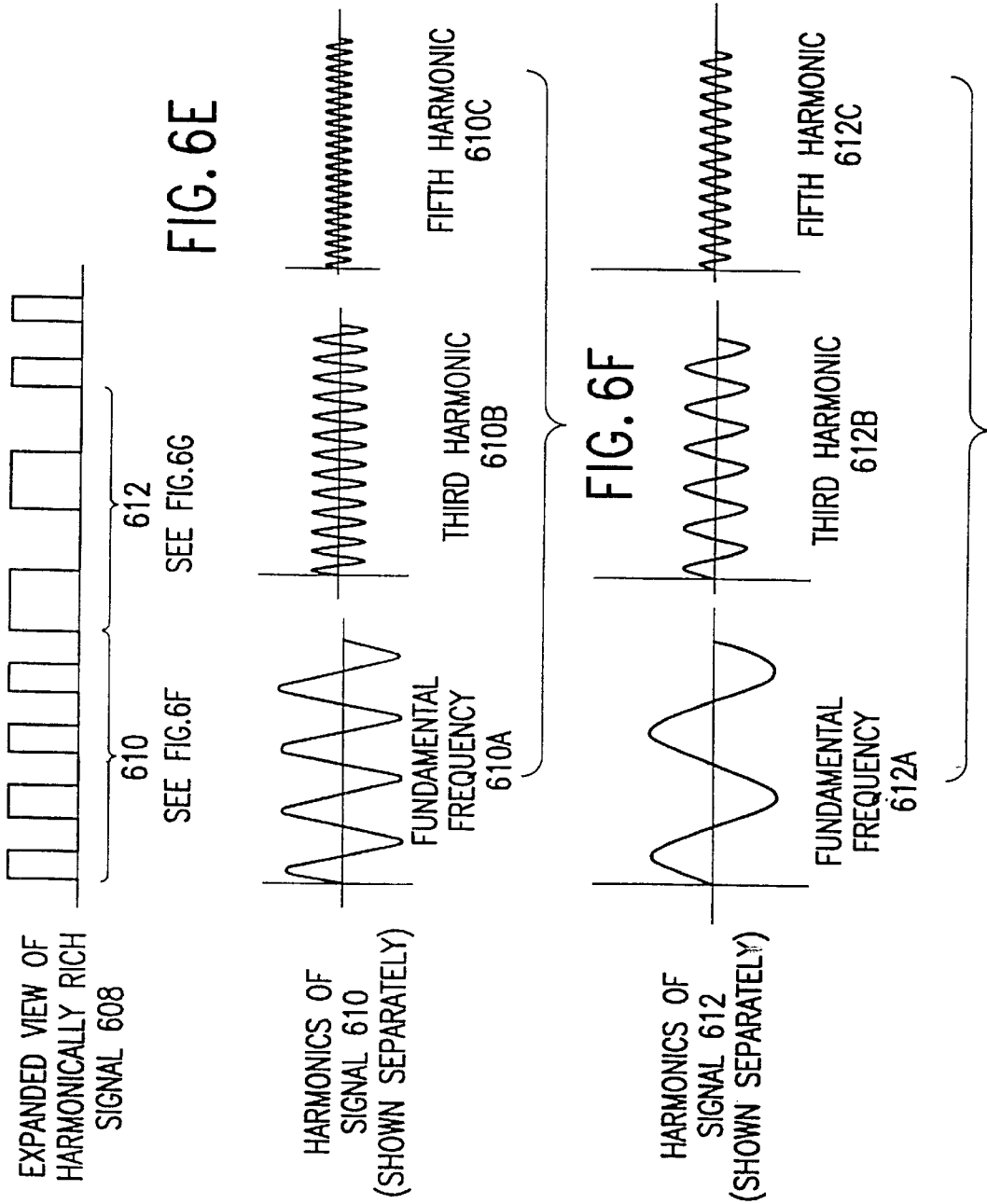
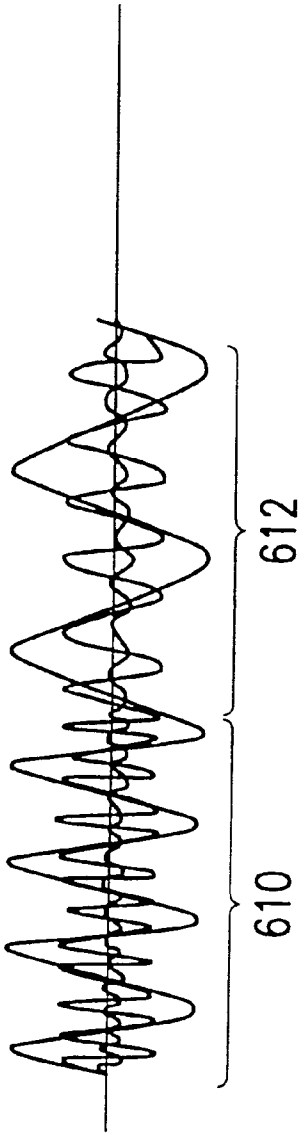


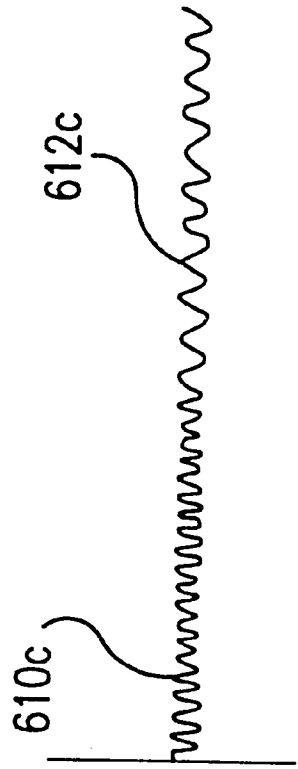
FIG. 6D





HARMONICS OF  
SIGNALS 610 AND  
612  
(SHOWN SIMULTANEOUSLY  
BUT NOT SUMMED)

FIG. 6H



FILTERED  
OUTPUT  
SIGNAL  
614

FIG. 6I

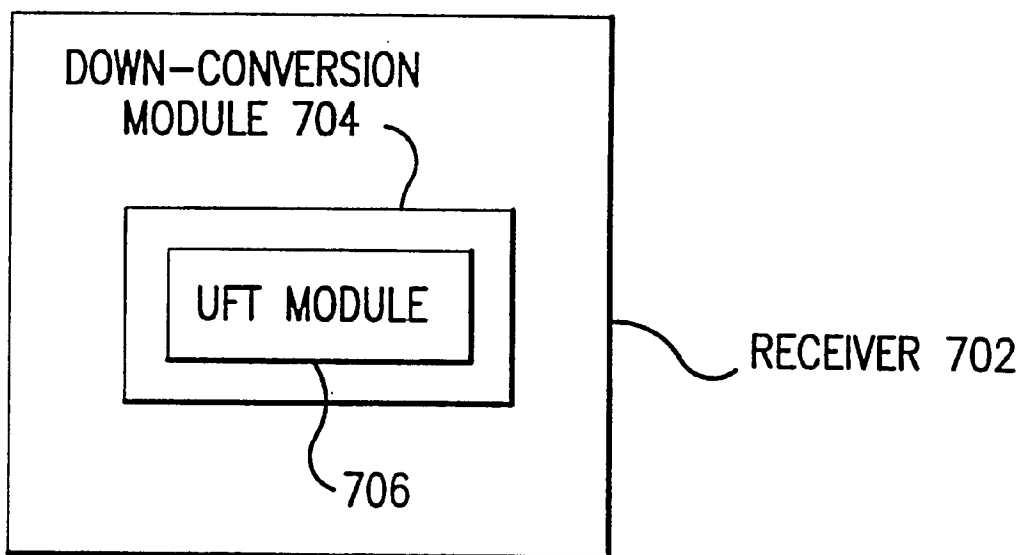


FIG. 7

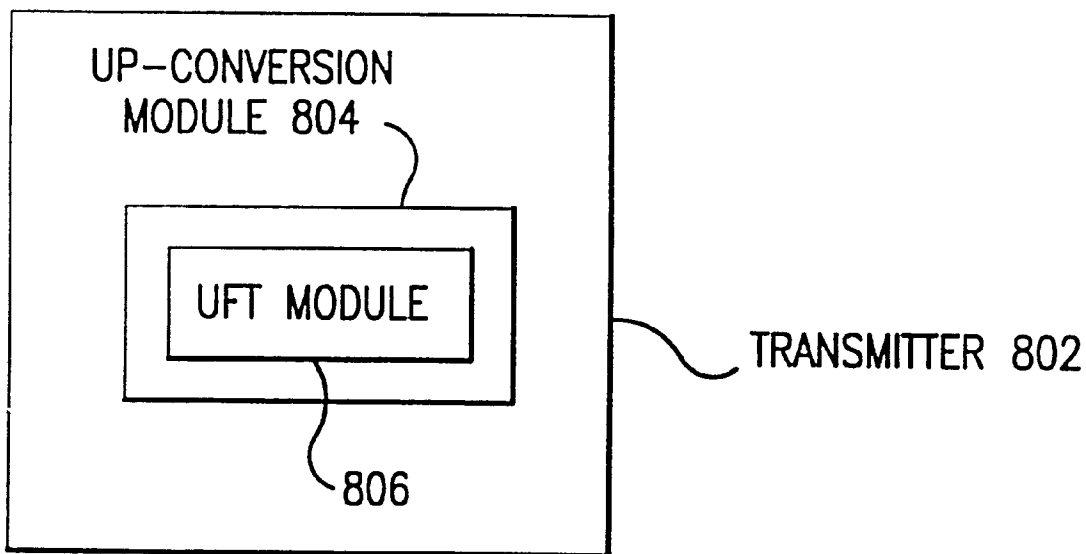


FIG. 8

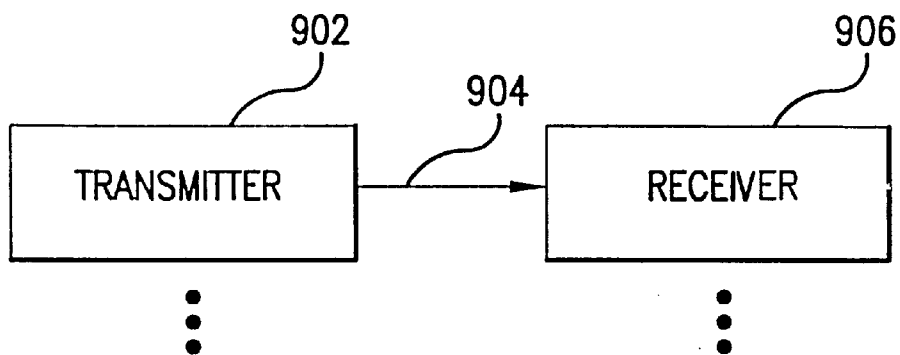


FIG. 9

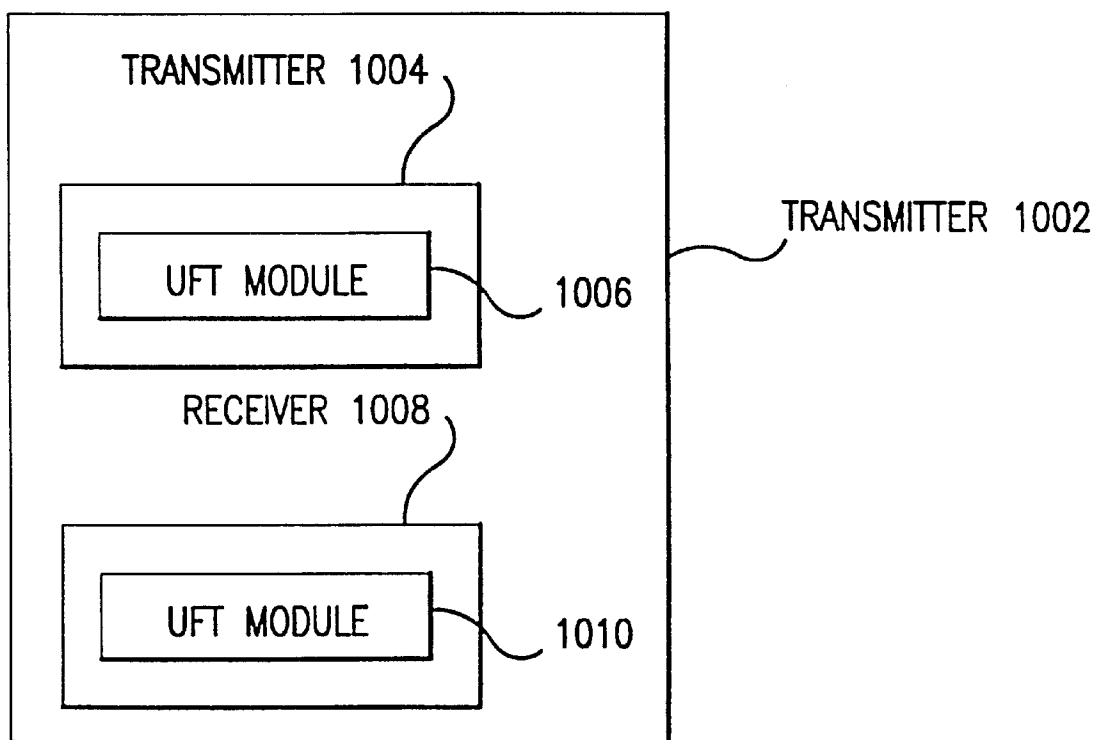


FIG. 10

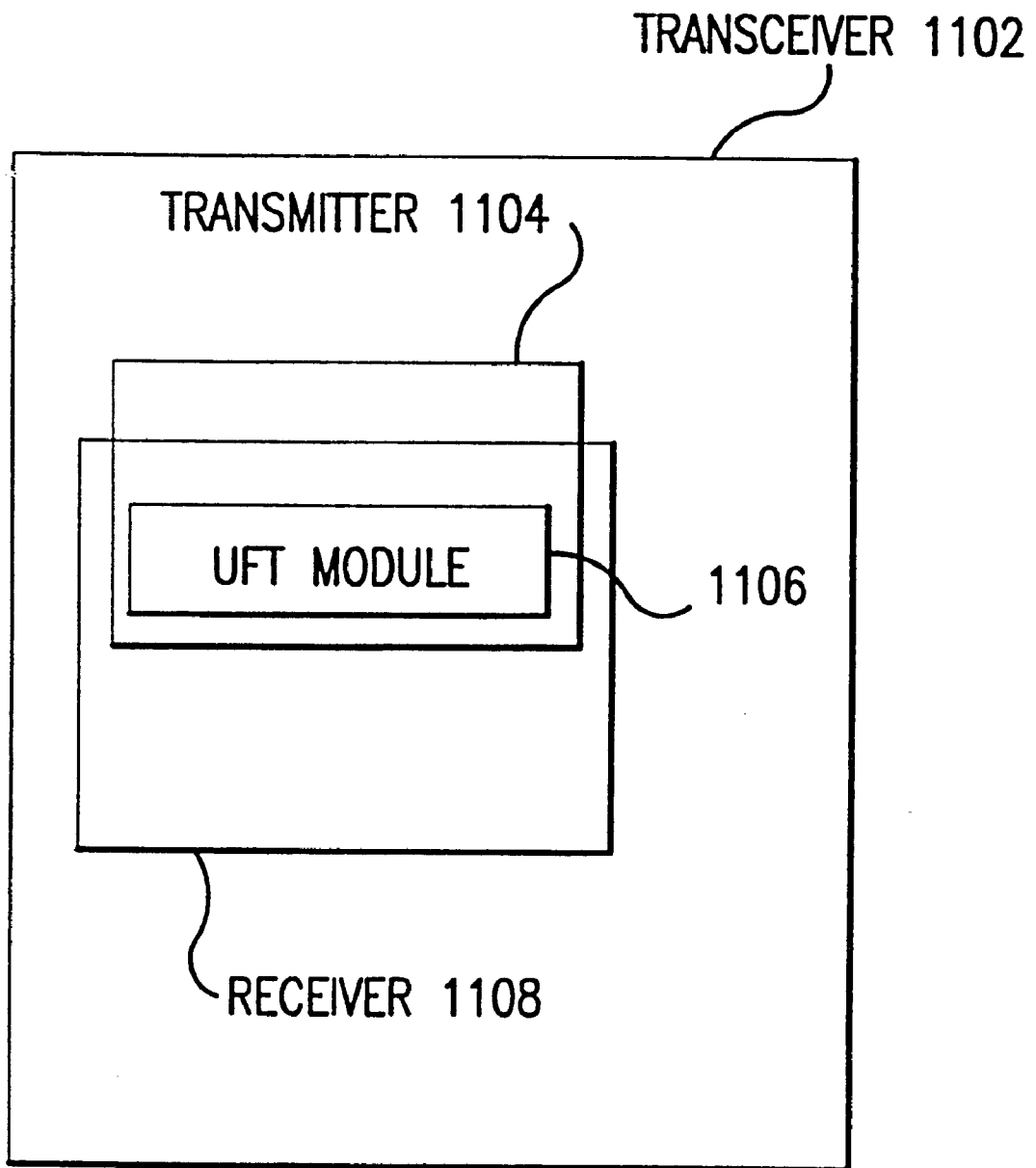


FIG. 11

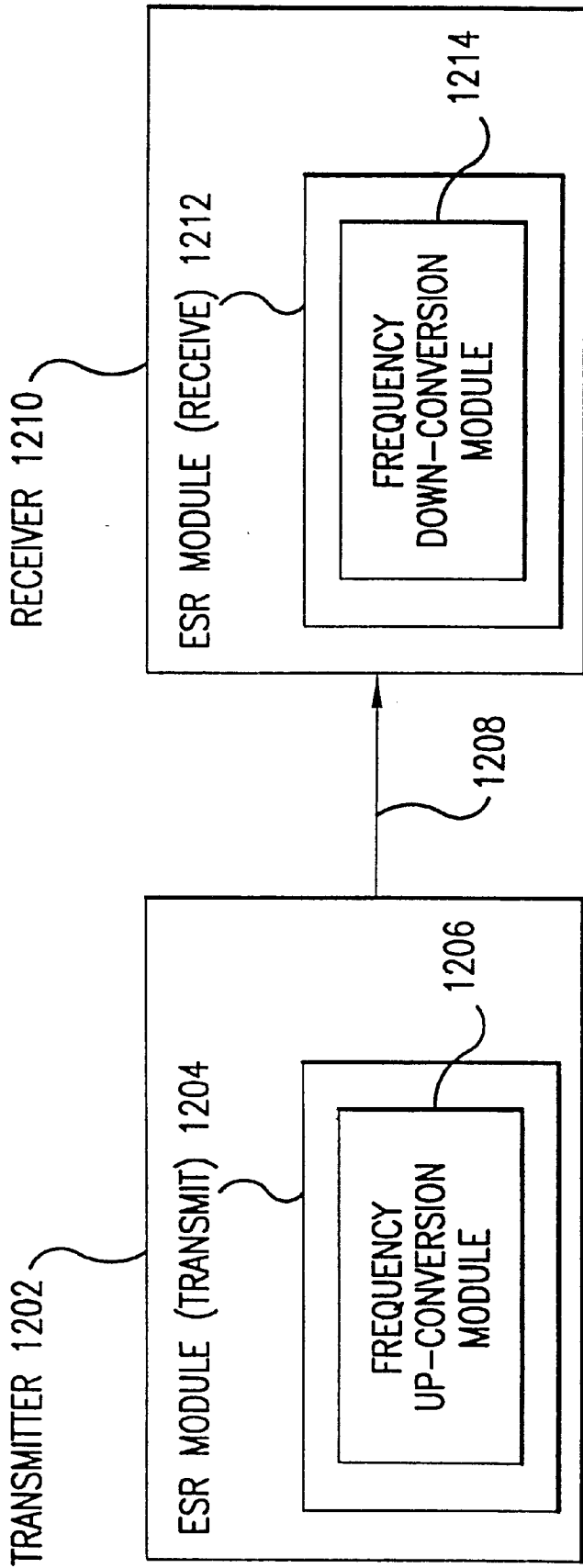


FIG. 12



UNIFIED DOWN-CONVERTING  
AND FILTERING (UDF) MODULE 1302

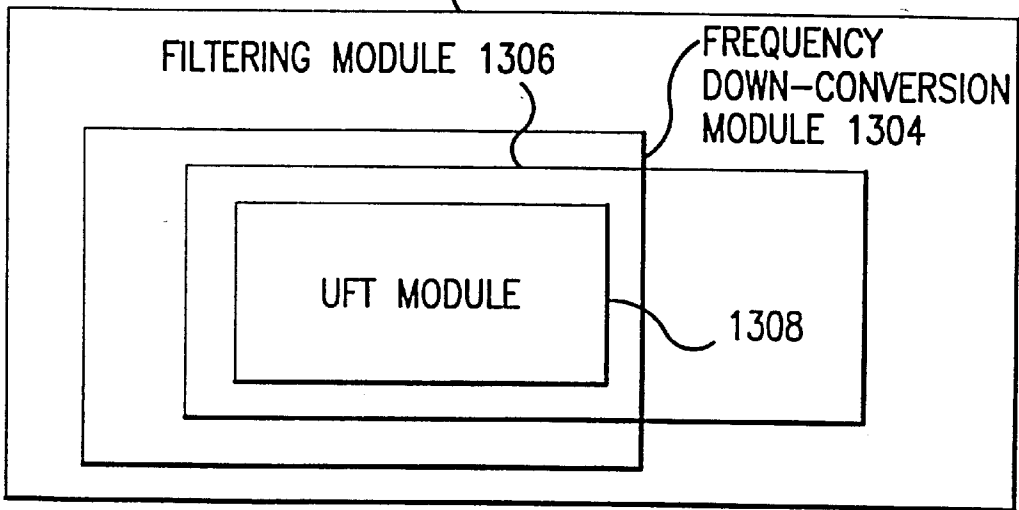


FIG. 13

RECEIVER 1402

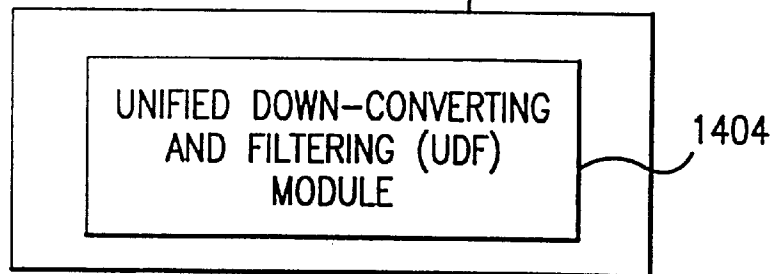


FIG. 14

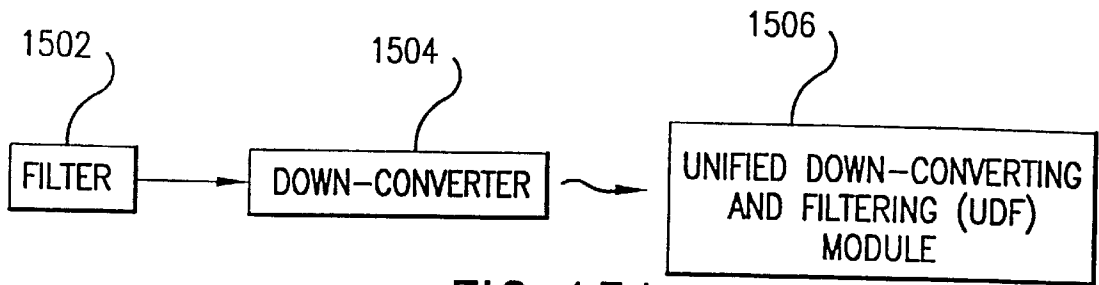


FIG. 15A

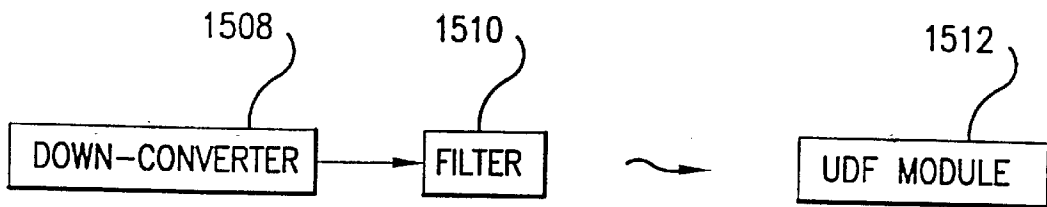


FIG. 15B

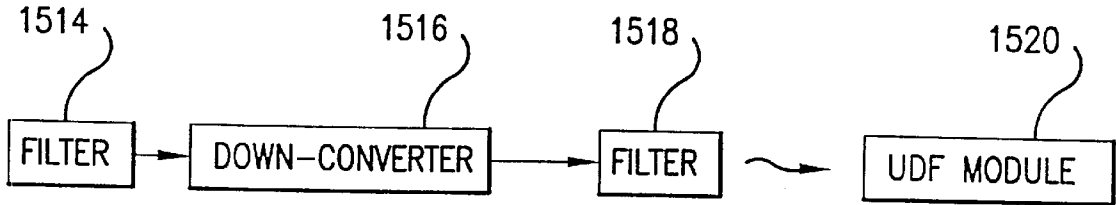


FIG. 15C

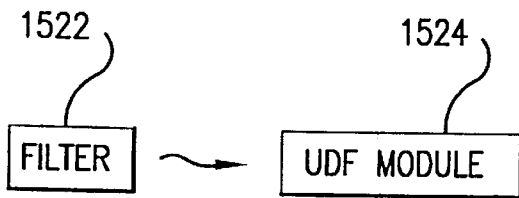


FIG. 15D

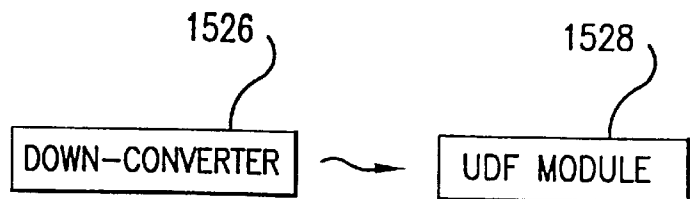


FIG. 15E

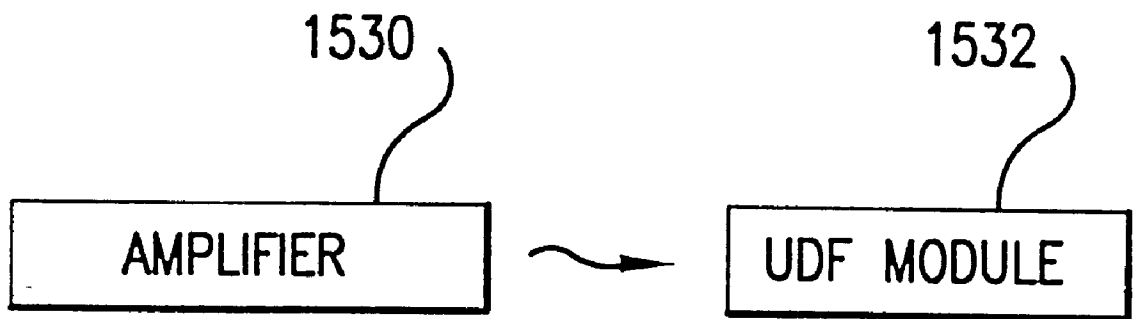


FIG. 15F

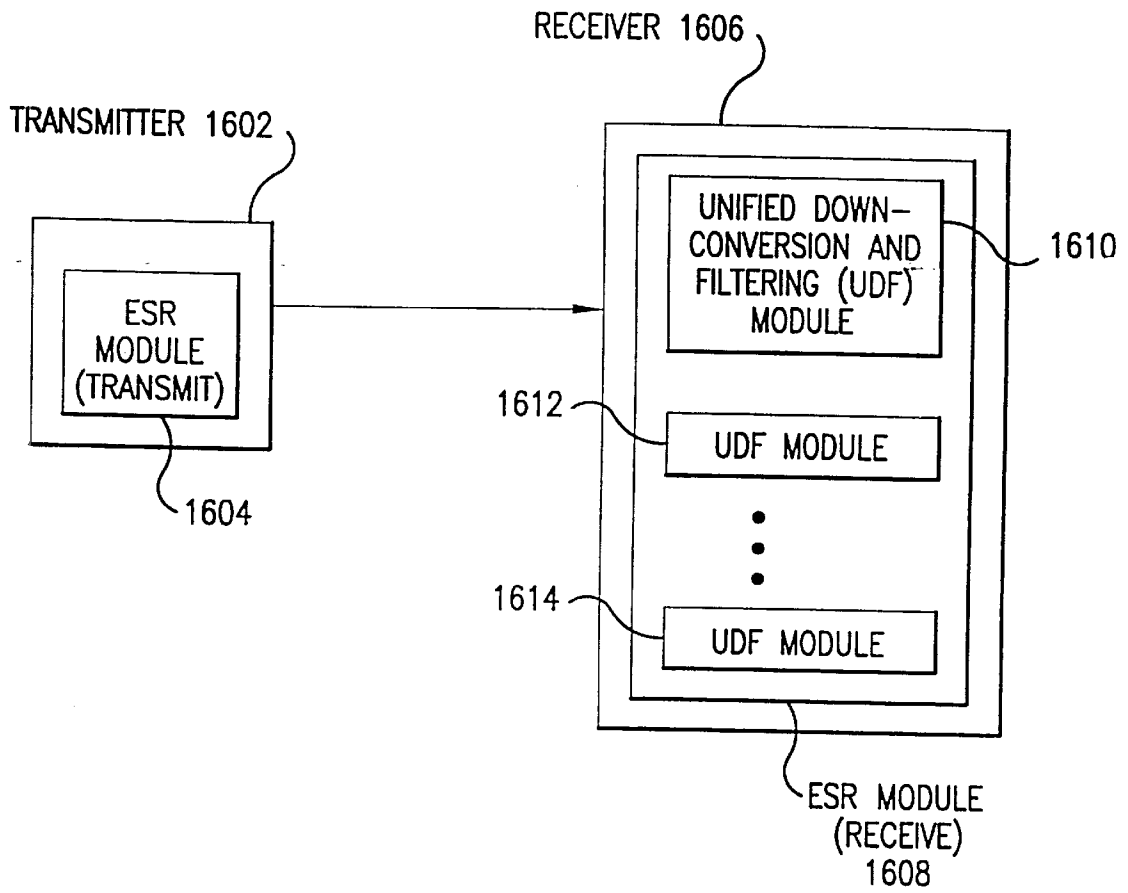


FIG. 16

UNIFIED DOWNCONVERTING AND  
FILTERING (UDF) MODULE 1702

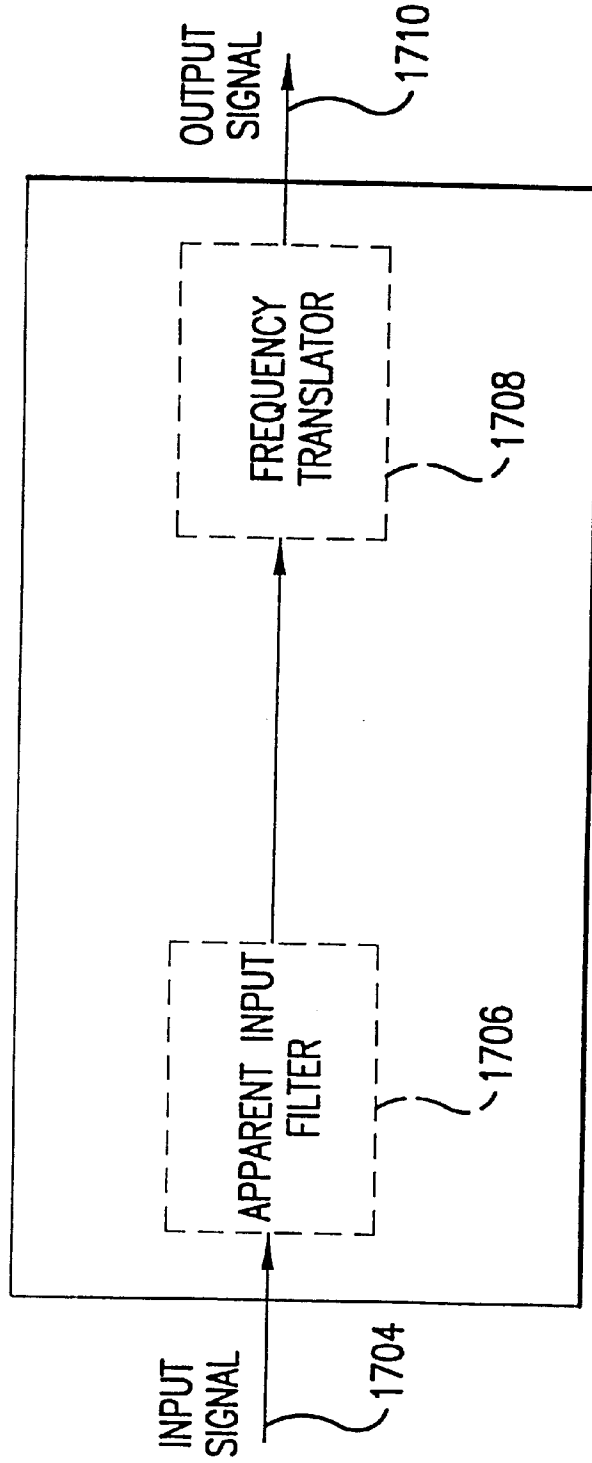


FIG. 17

1802

TIME NODE	t-1 (RISING EDGE OF $\phi_1$ )	t-1 (RISING EDGE OF $\phi_2$ )	t (RISING EDGE OF $\phi_1$ )	t (RISING EDGE OF $\phi_2$ )	t+1 (RISING EDGE OF $\phi_1$ )
1902	$V_{t-1}$ <u>1804</u>	$V_{t-1}$ <u>1808</u>	$V_t$ <u>1816</u>	$V_t$ <u>1826</u>	$V_{t+1}$ <u>1838</u>
1904	—	$V_{t-1}$ <u>1810</u>	$V_{t-1}$ <u>1818</u>	$V_t$ <u>1828</u>	$V_t$ <u>1840</u>
1906	$V_{t-1}$ <u>1806</u>	$V_{t-1}$ <u>1812</u>	$V_t$ <u>1820</u>	$V_t$ <u>1830</u>	$V_{t+1}$ <u>1842</u>
1908	—	$V_{t-1}$ <u>1814</u>	$V_{t-1}$ <u>1822</u>	$V_t$ <u>1832</u>	$V_t$ <u>1844</u>
1910	— <u>1807</u>	—	$V_{t-1}$ <u>1824</u>	$V_{t-1}$ <u>1834</u>	$V_t$ <u>1846</u>
1912	—	— <u>1815</u>	—	$V_{t-1}$ <u>1836</u>	$V_{t-1}$ <u>1848</u>
1918	—	—	—	—	$V_t$ <u>1850</u> $0.1*V_{t-}$ $0.8*V_{t-1}$

FIG. 18

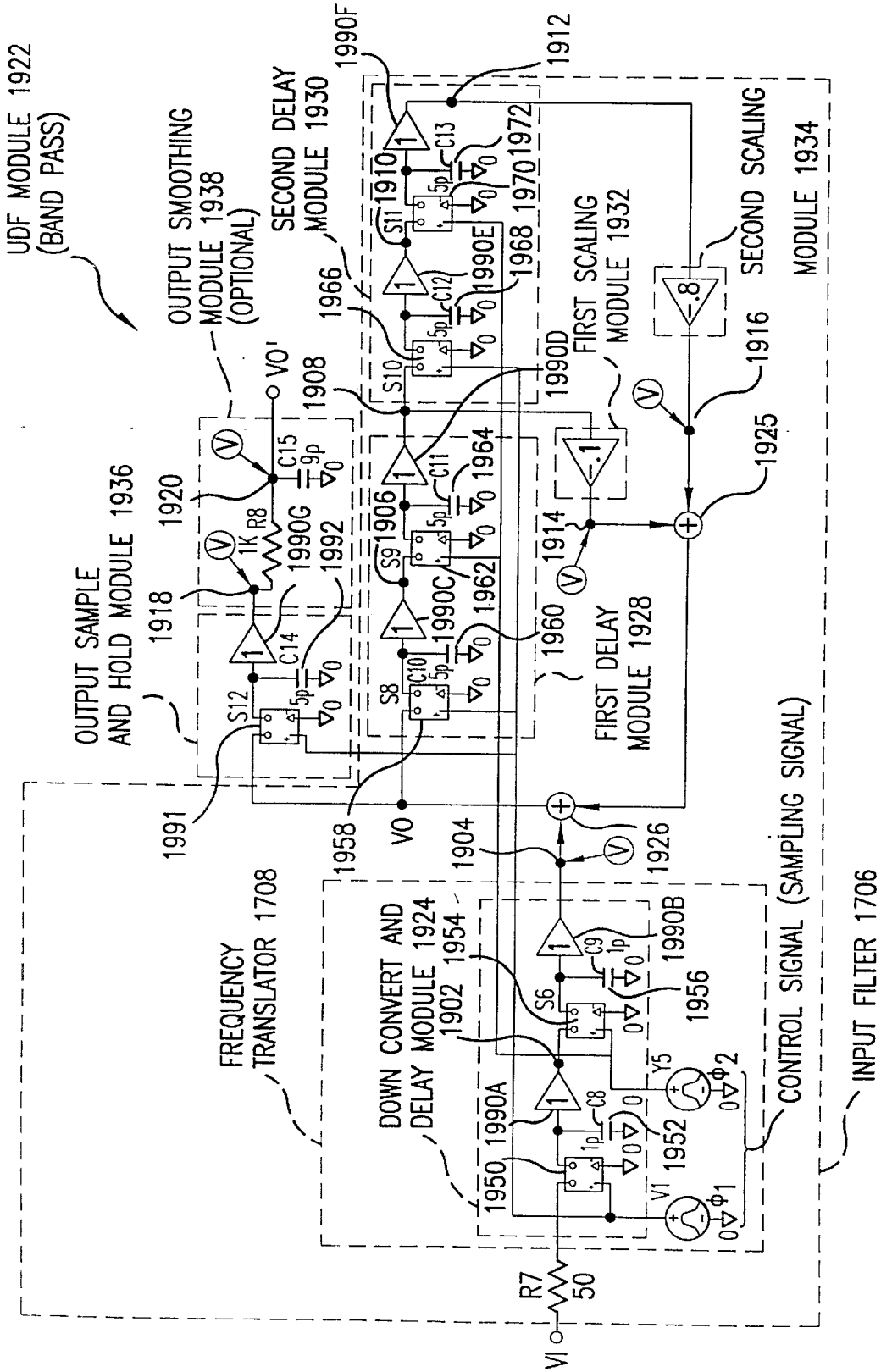


FIG. 19

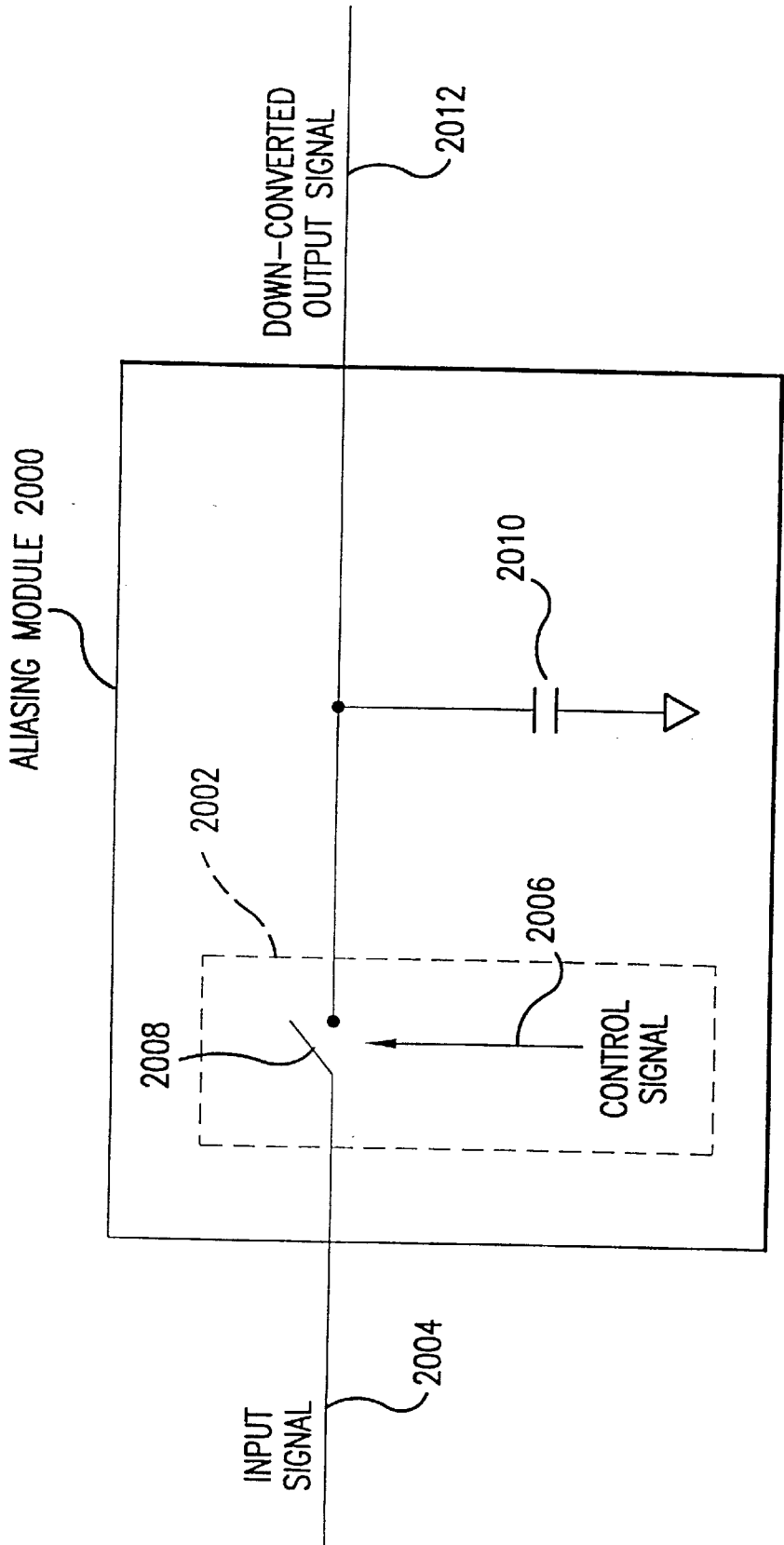


FIG. 20A



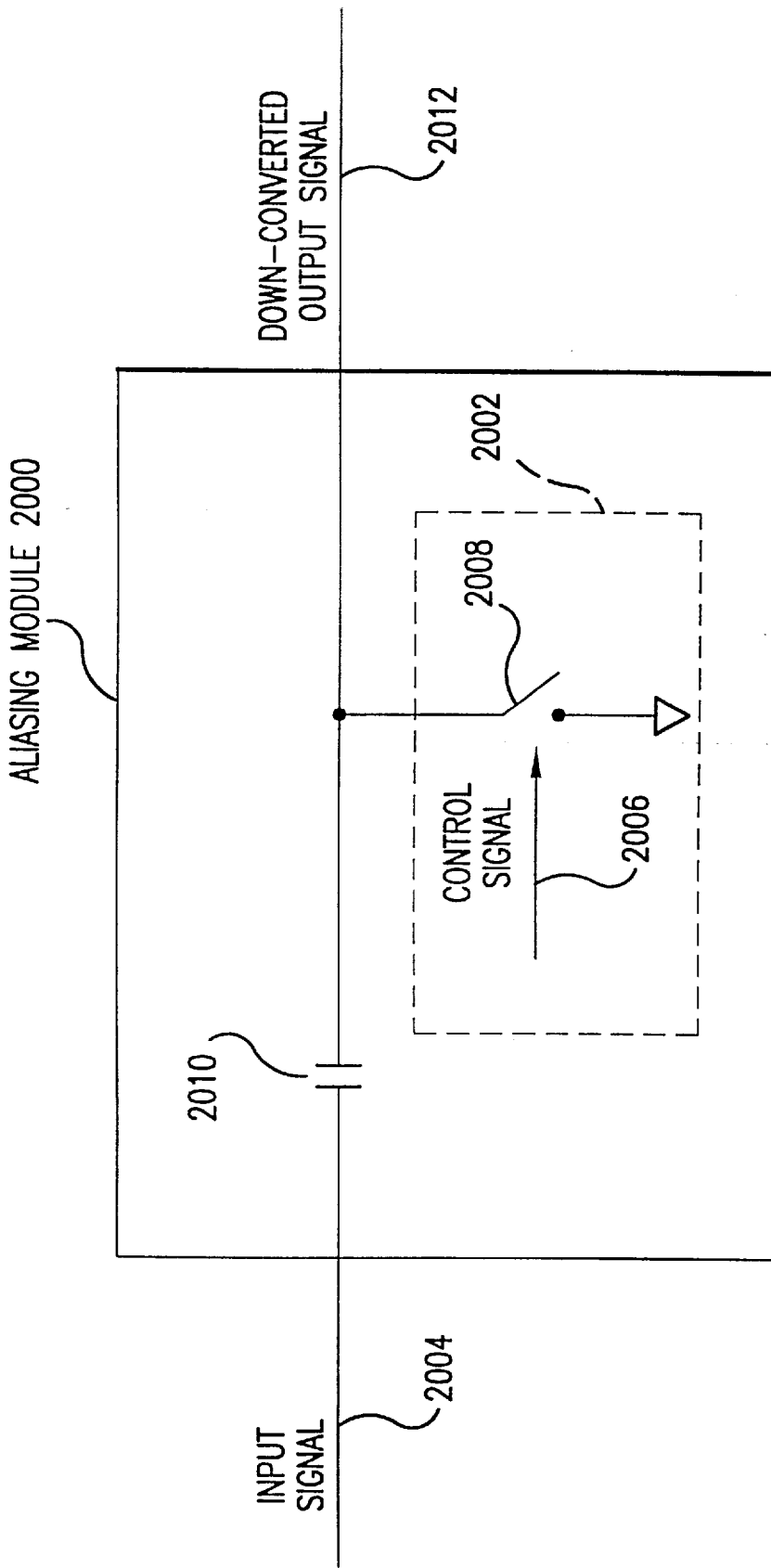


FIG. 20A-1

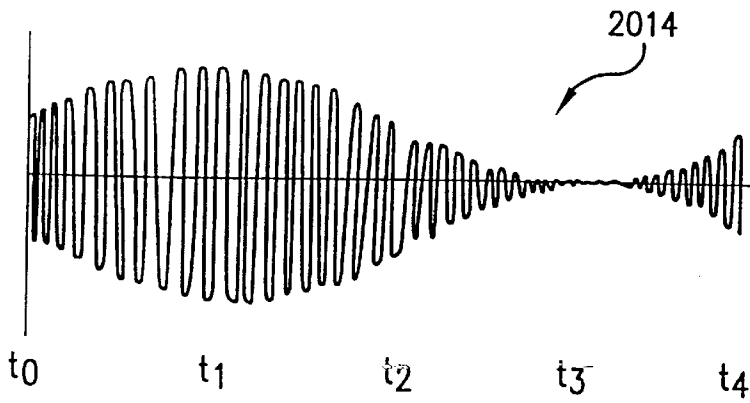


FIG. 20B

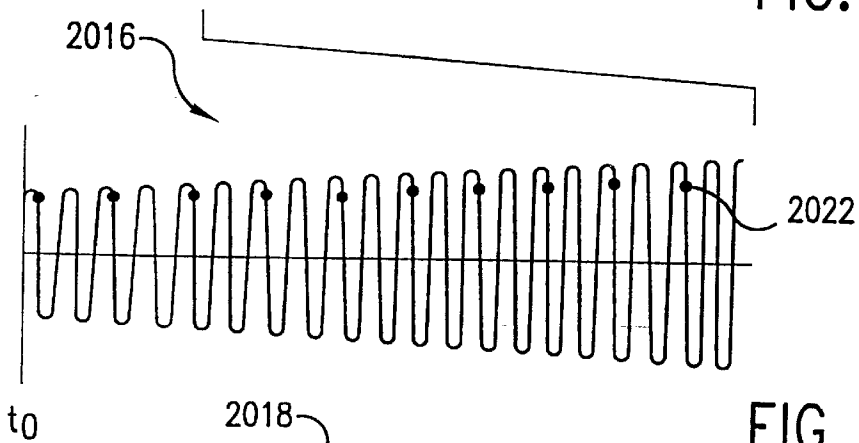


FIG. 20C

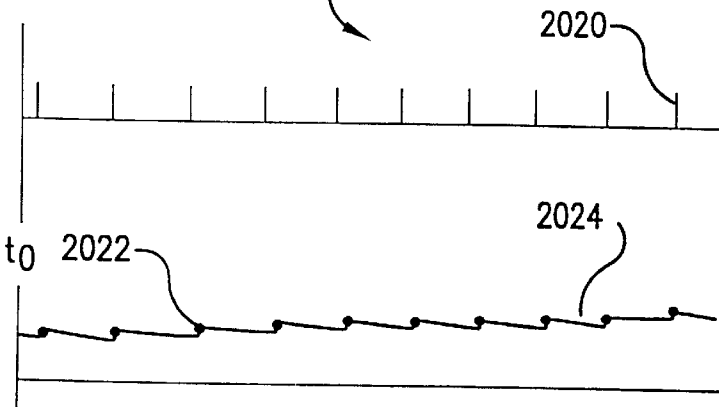


FIG. 20D

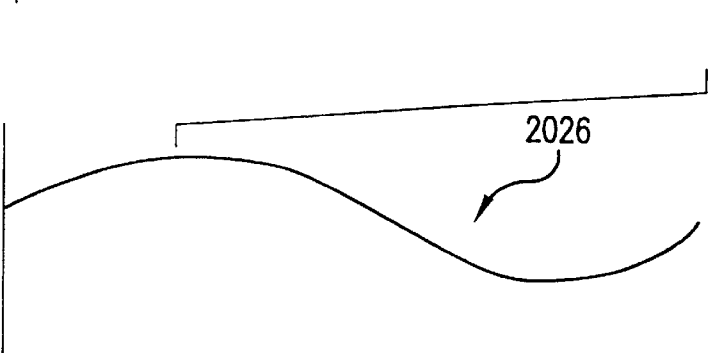


FIG. 20E

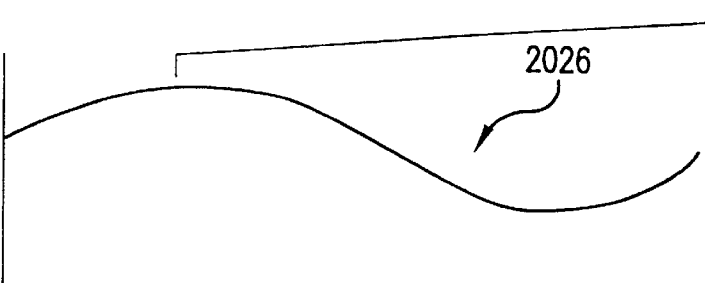


FIG. 20F

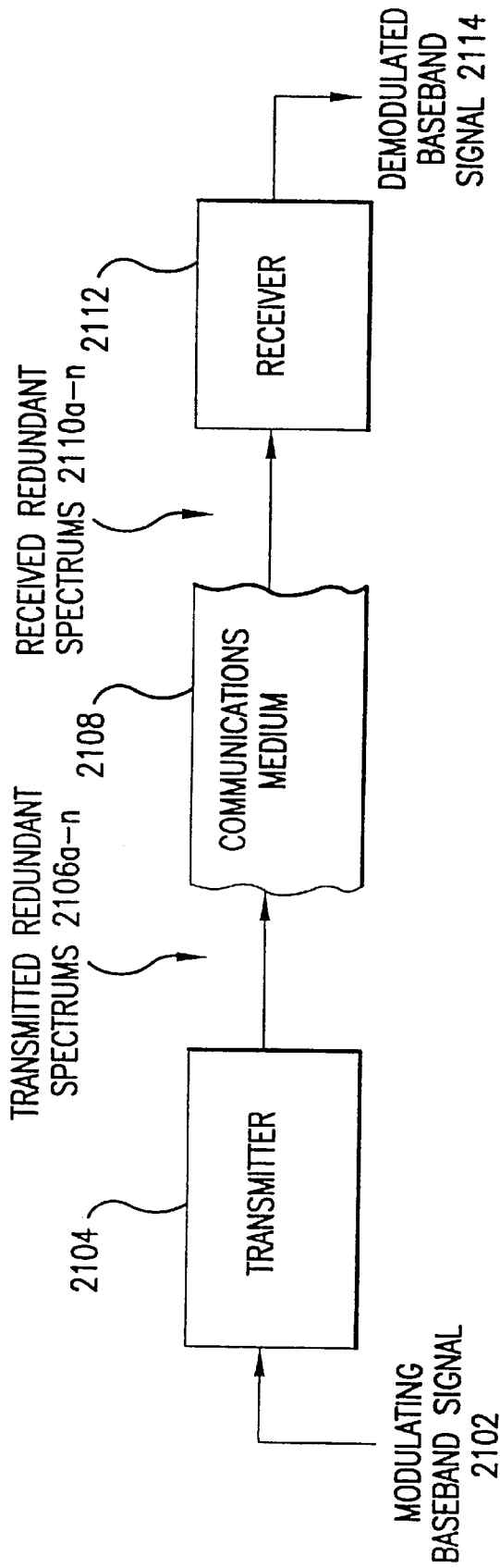


FIG. 21



FIG. 22A

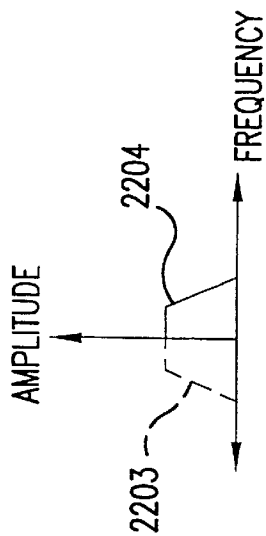


FIG. 22B

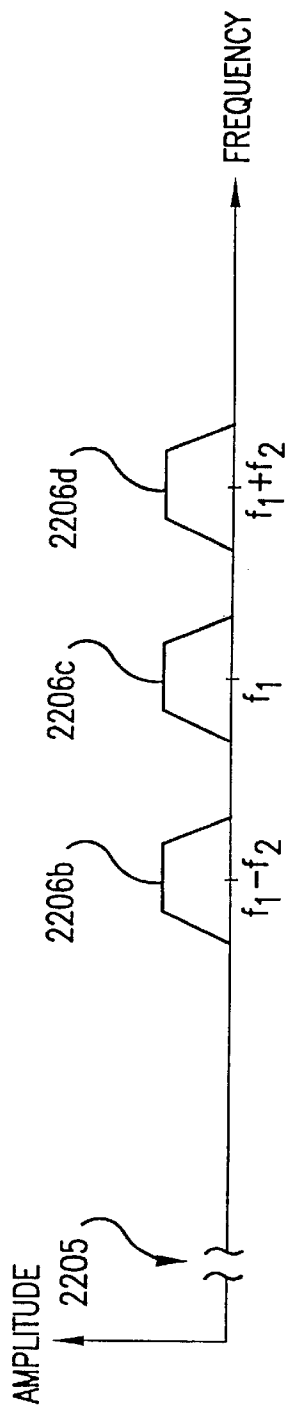


FIG. 22C

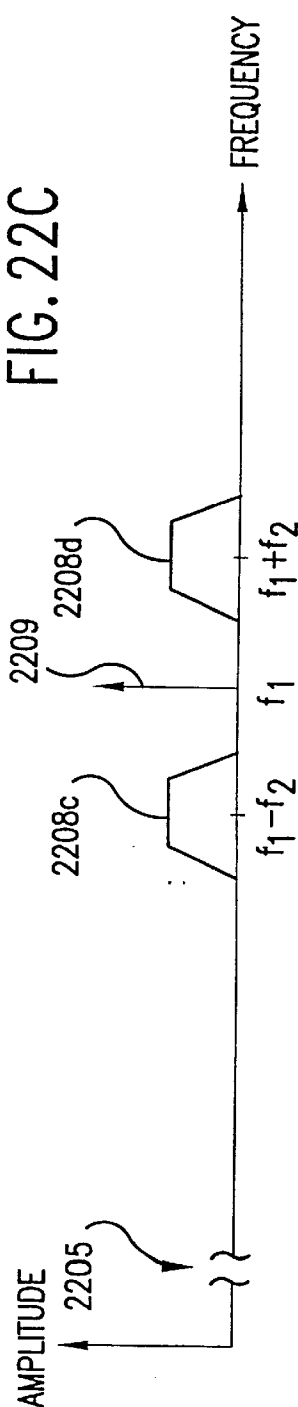


FIG. 22D

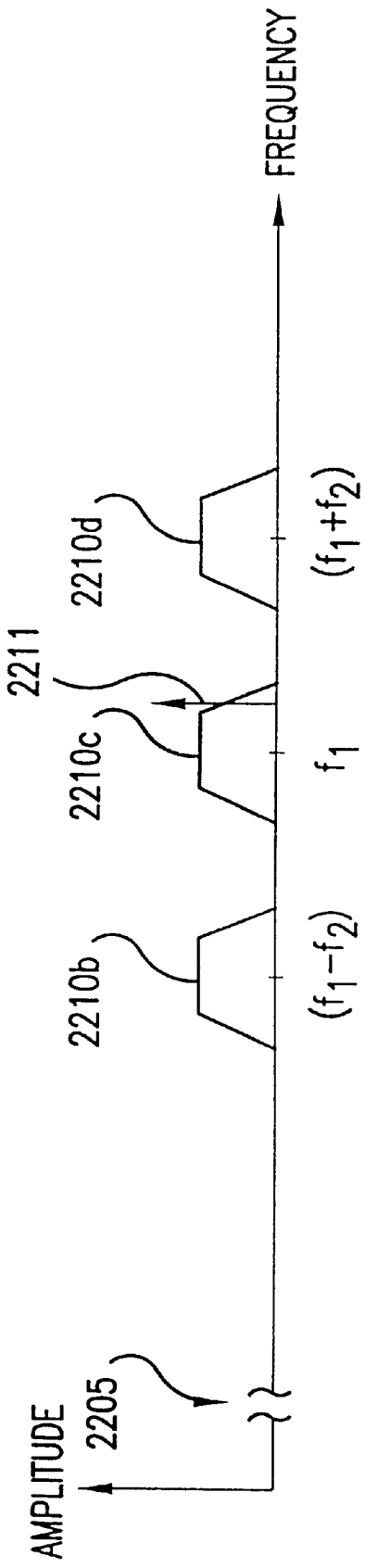


FIG. 22E

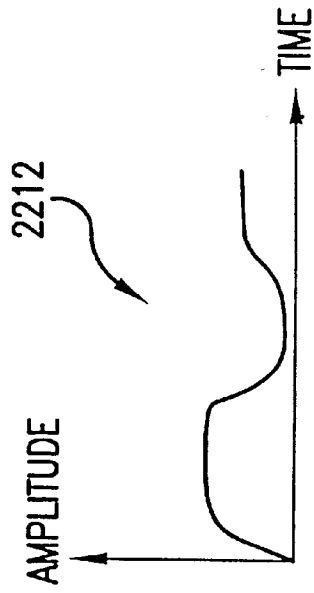


FIG. 22F

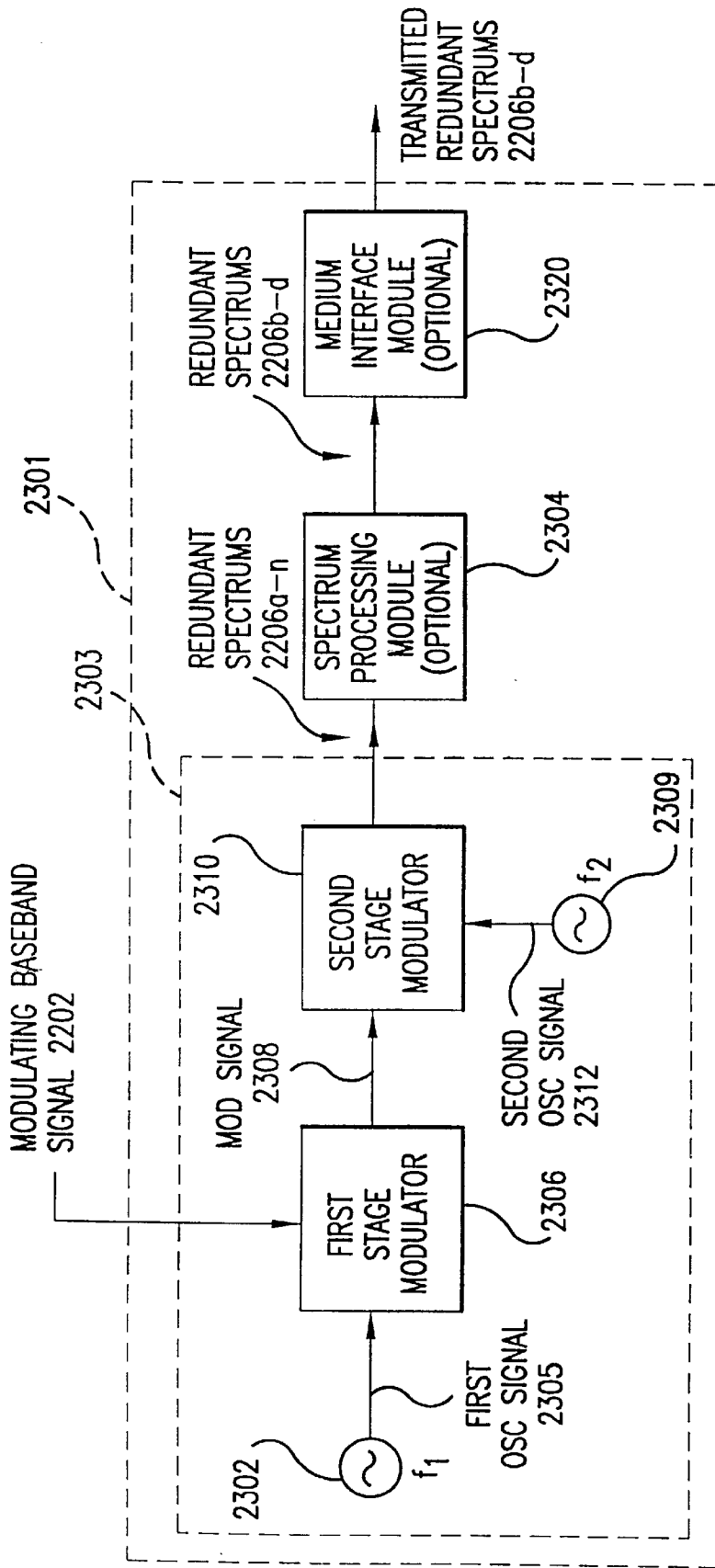


FIG. 23A

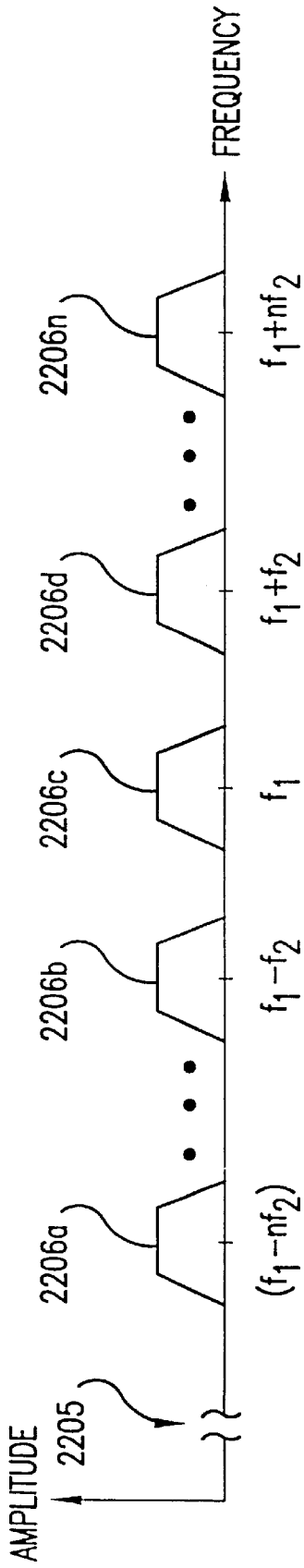


FIG. 23B

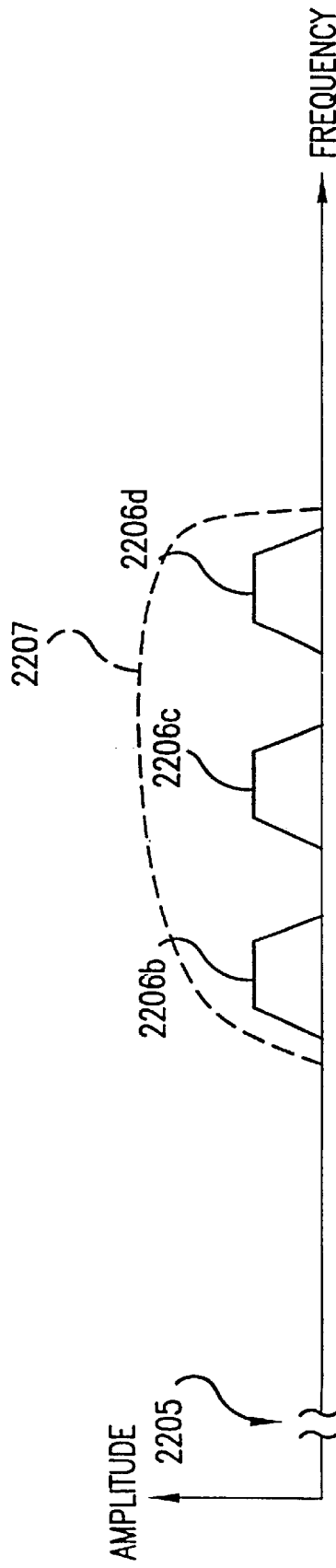


FIG. 23C

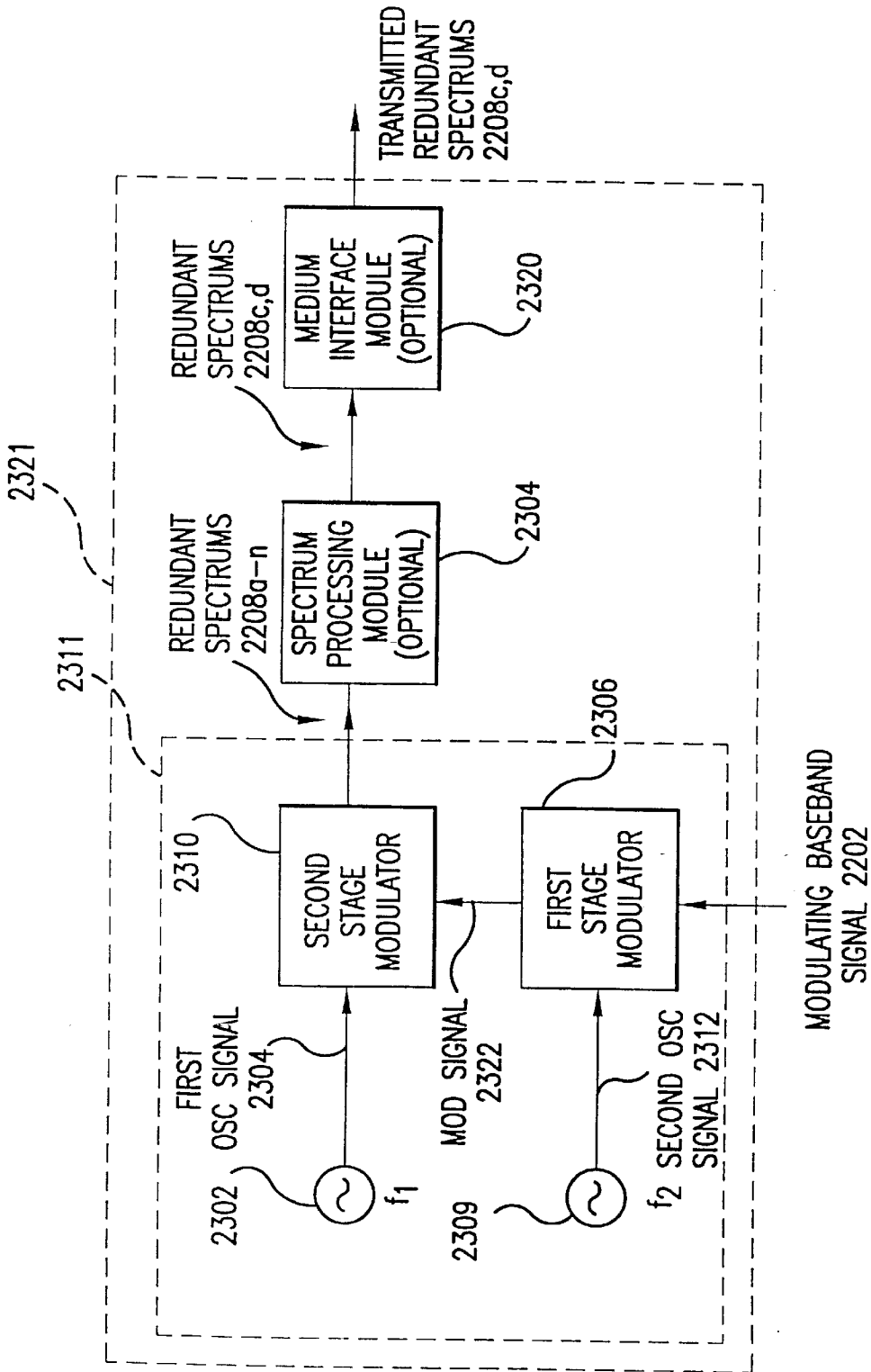


FIG. 23D



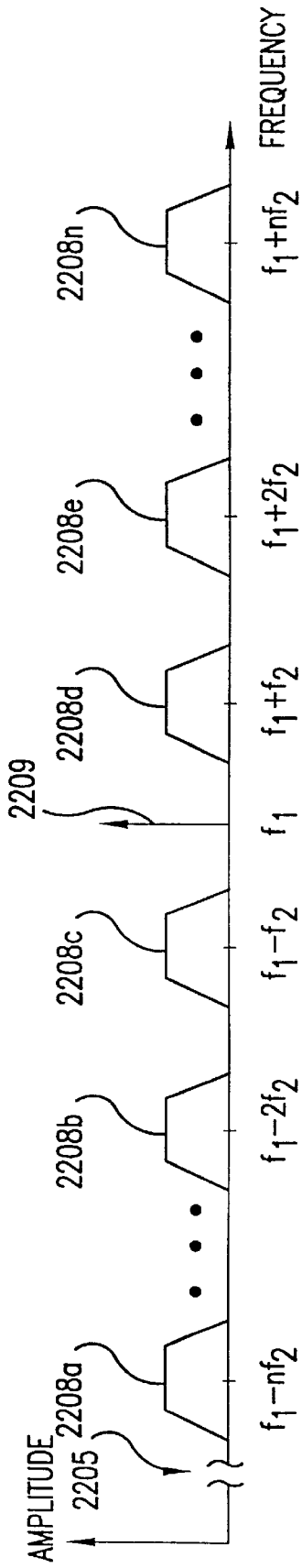


FIG. 23E

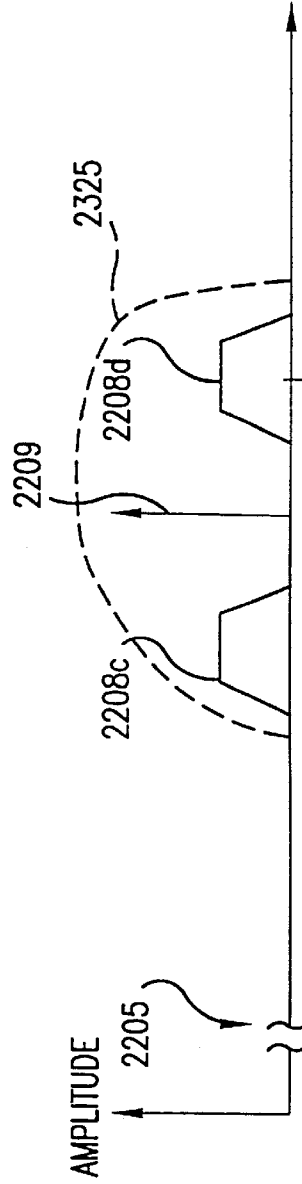


FIG. 23F

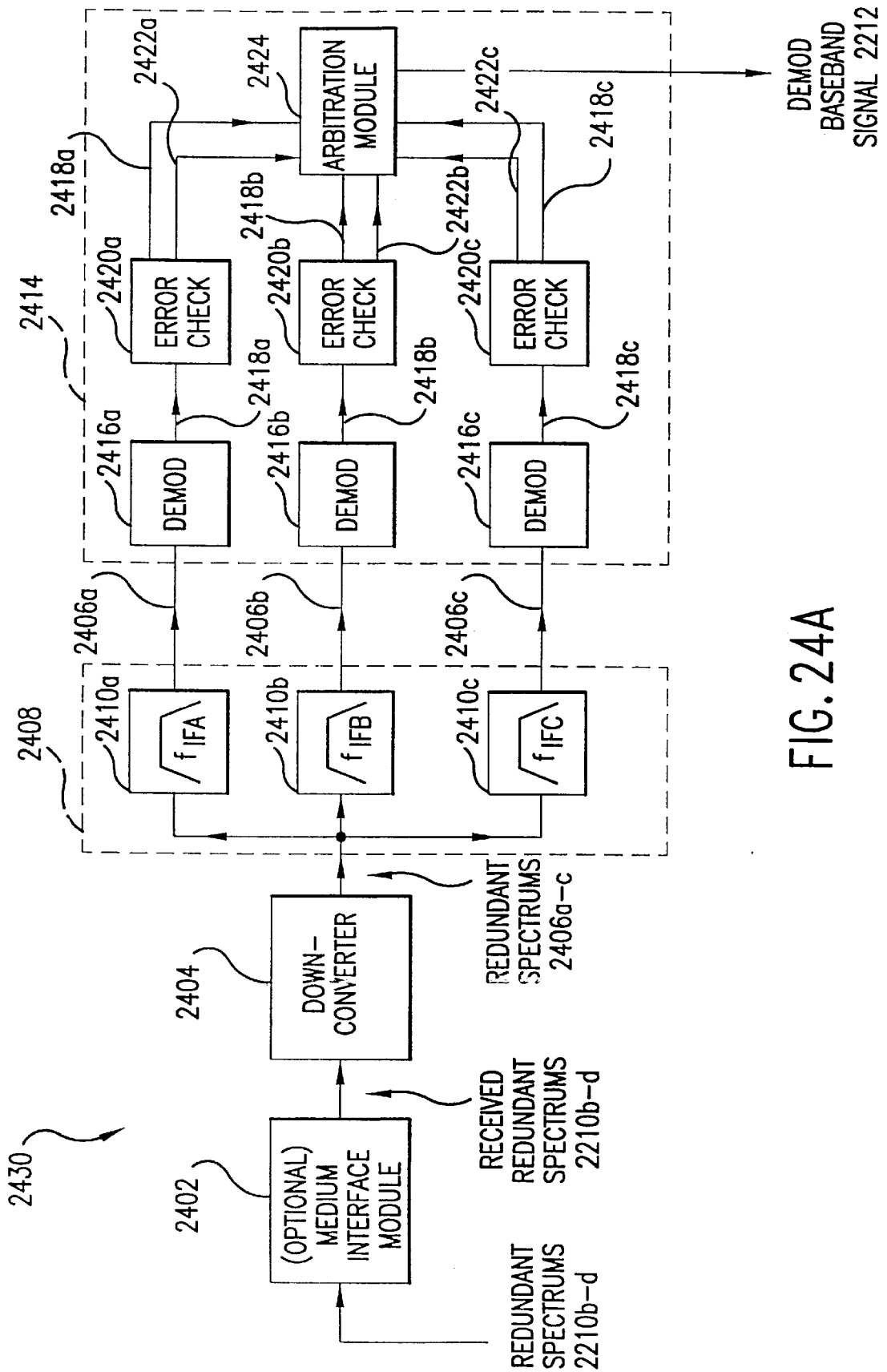


FIG. 24A

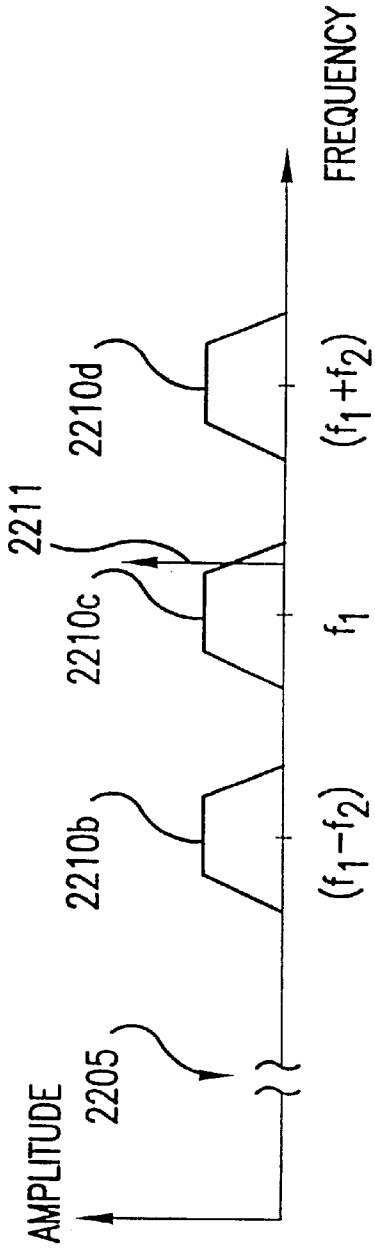


FIG. 24B

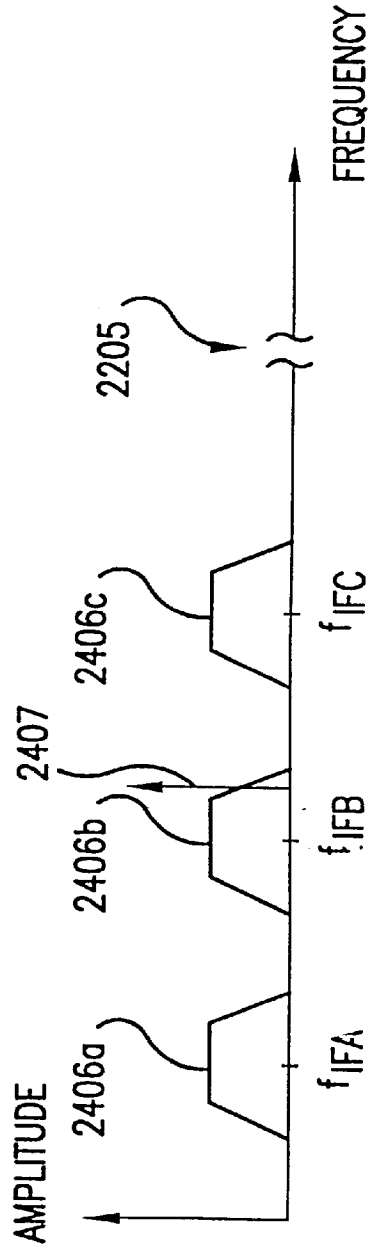


FIG. 24C

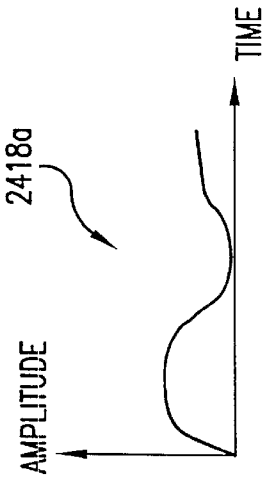


FIG. 24G

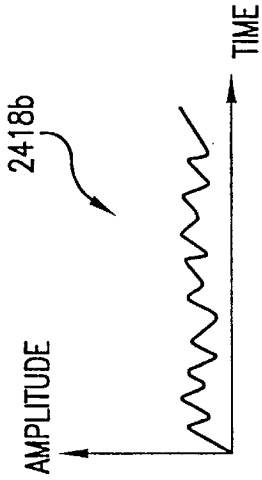


FIG. 24H

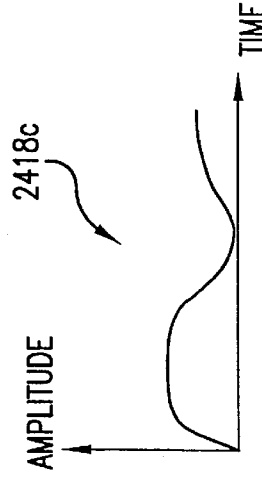


FIG. 24I

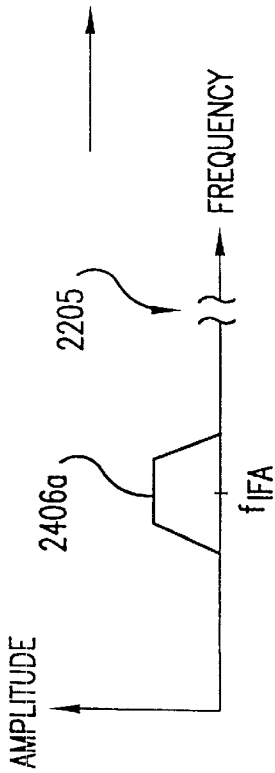


FIG. 24D

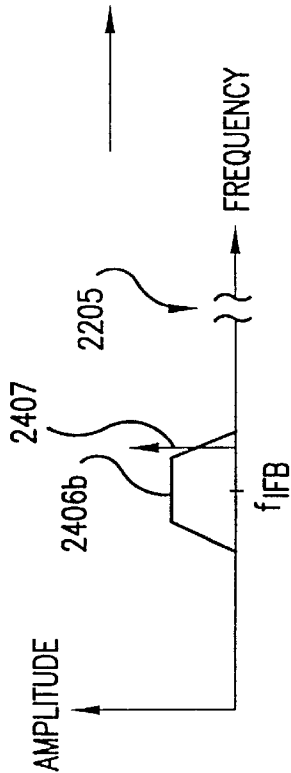


FIG. 24E

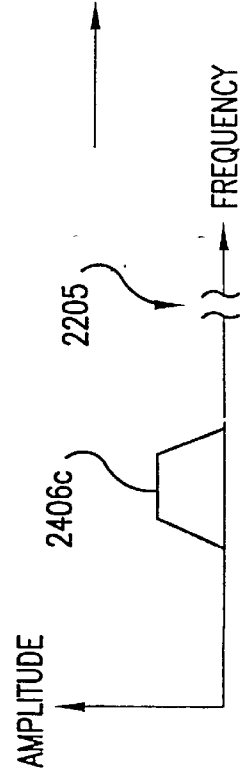


FIG. 24F

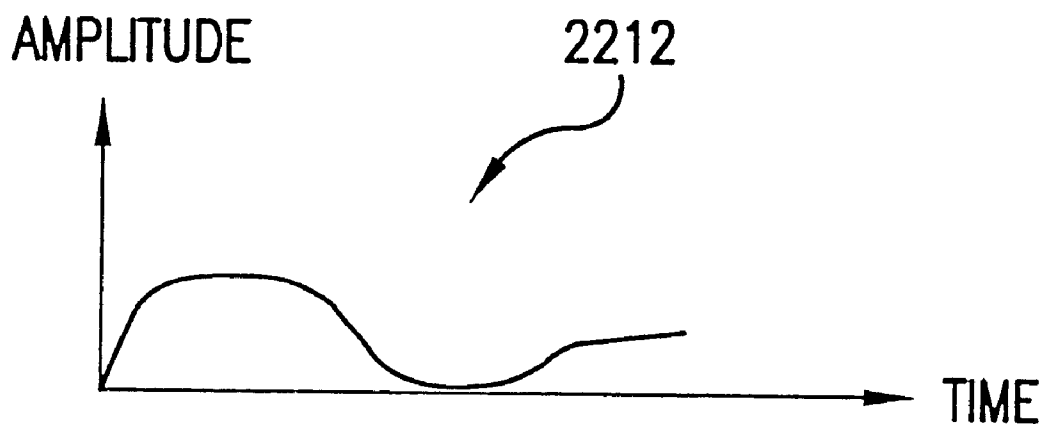


FIG. 24J

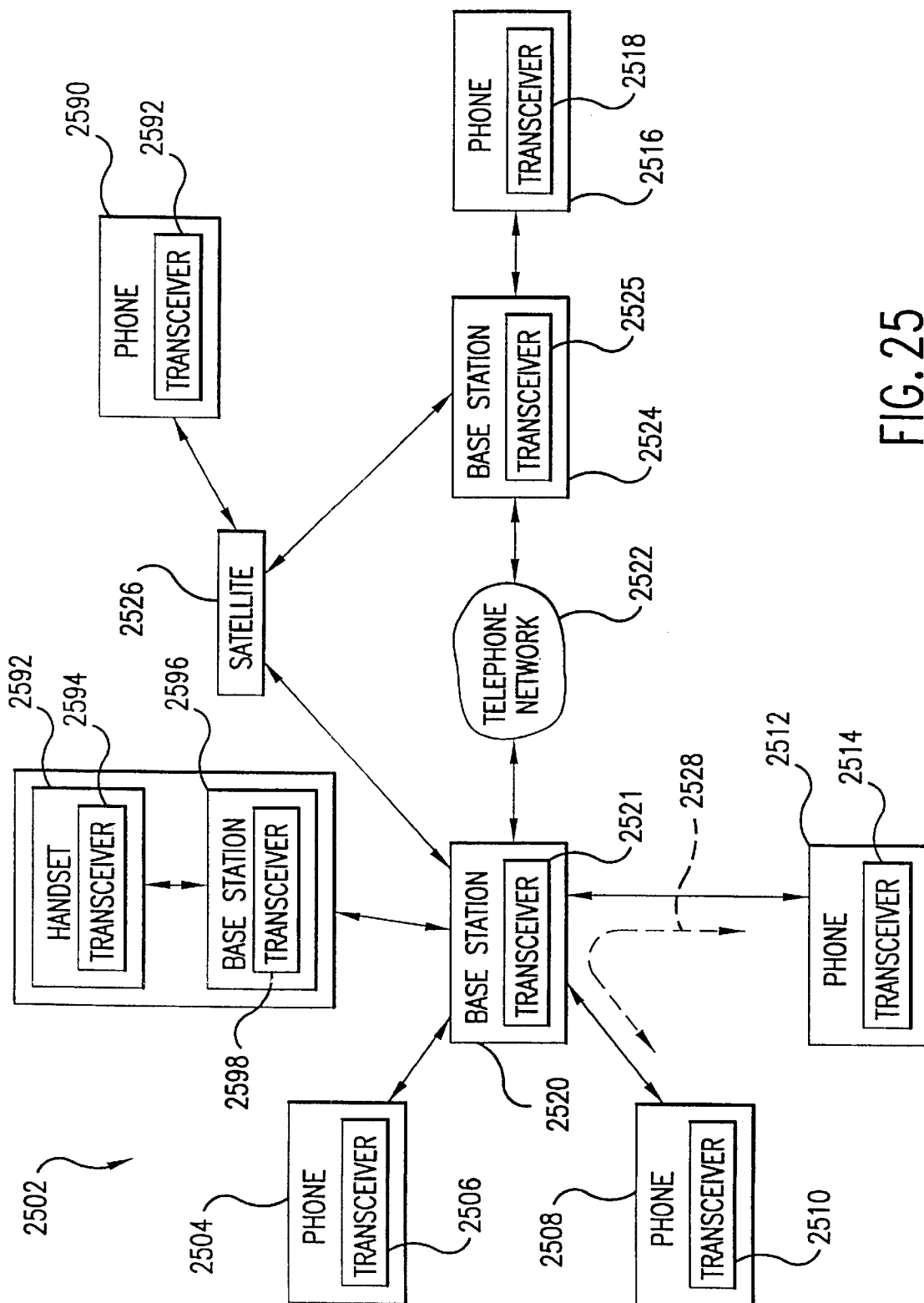


FIG. 25

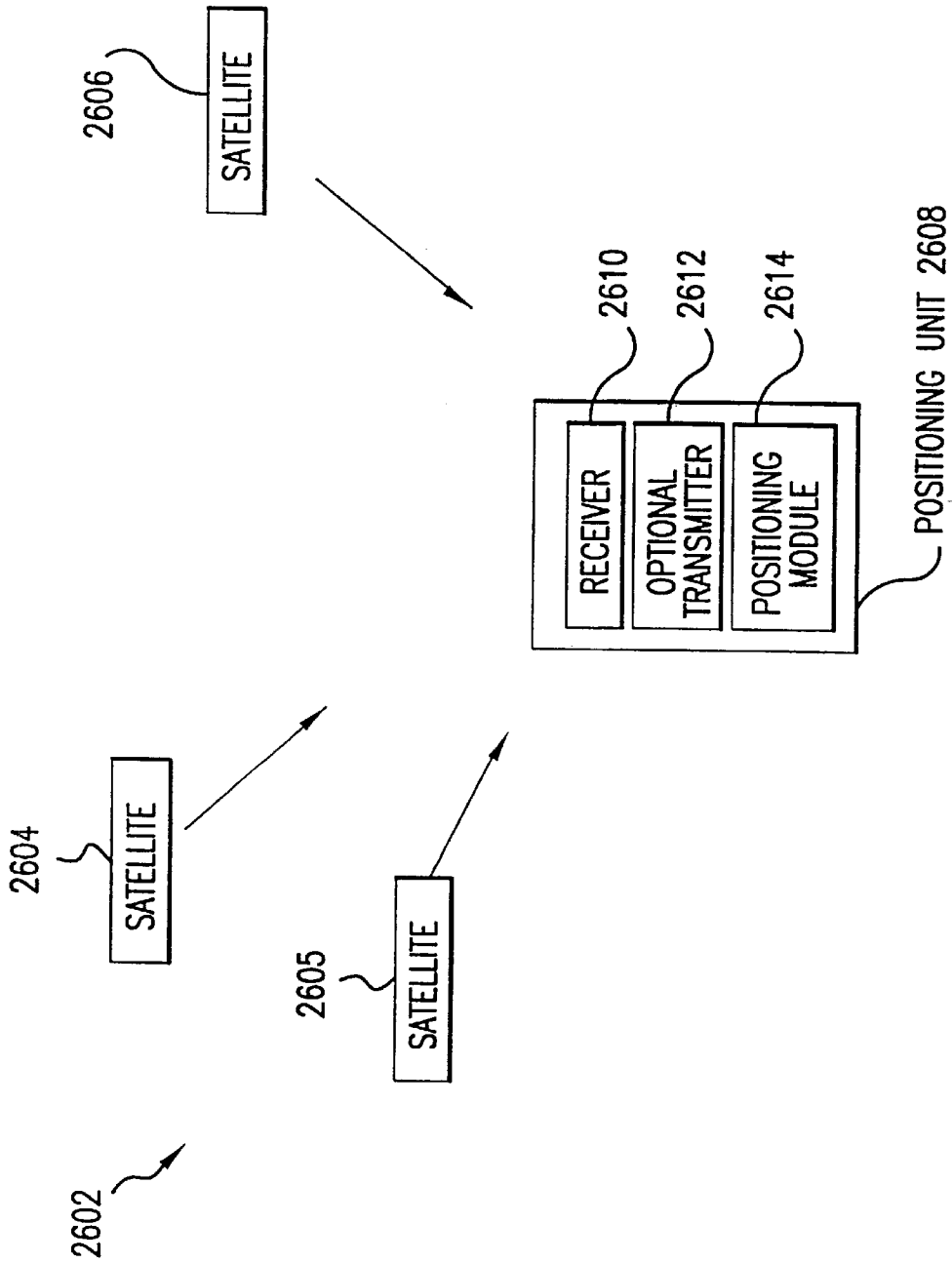


FIG. 26

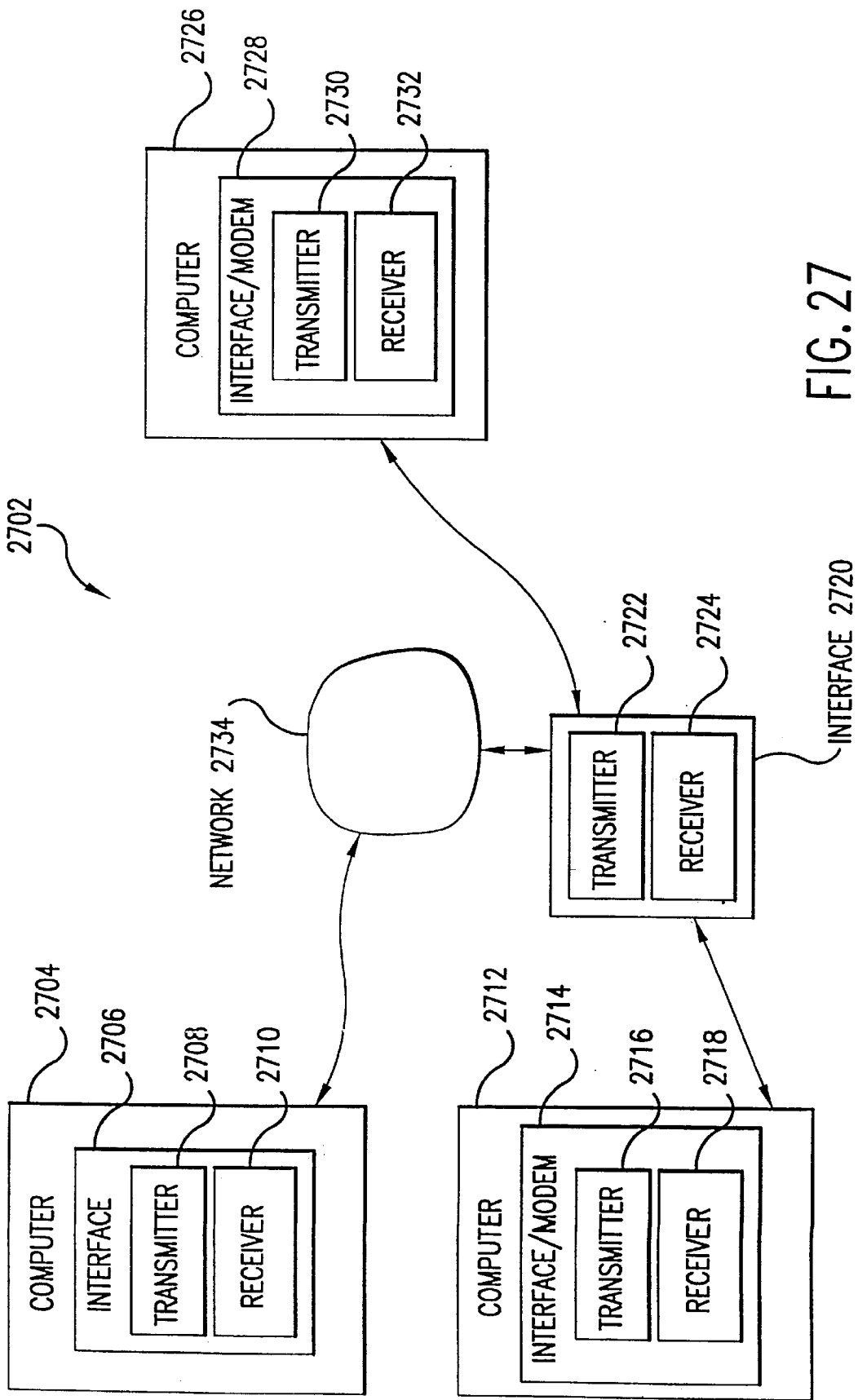


FIG. 27



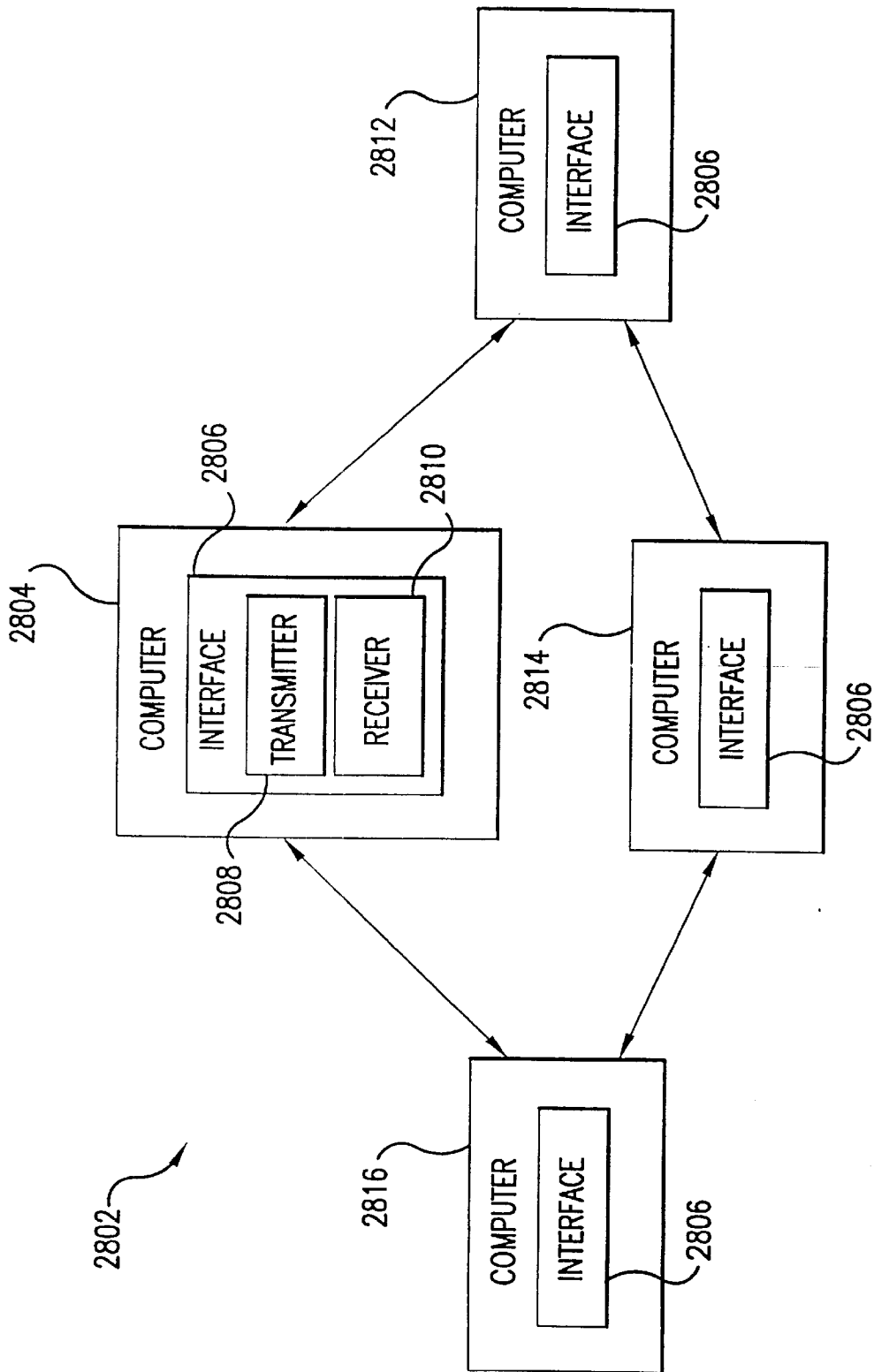


FIG. 28

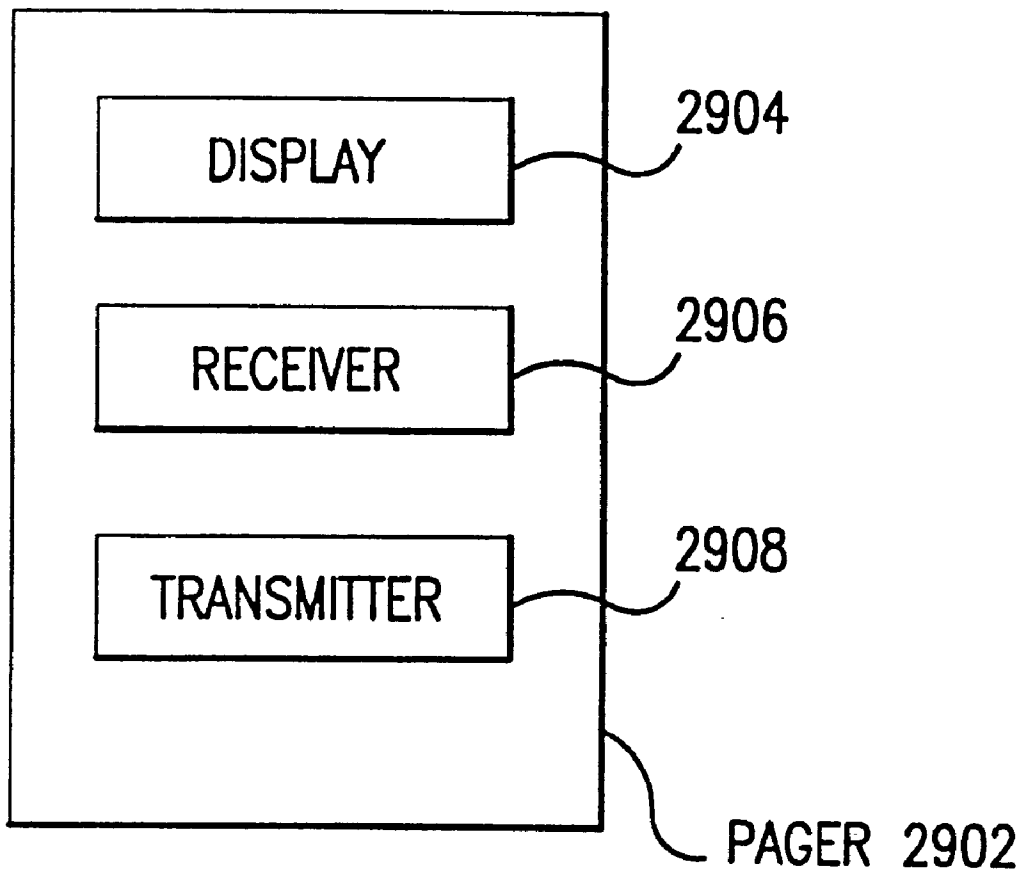


FIG. 29

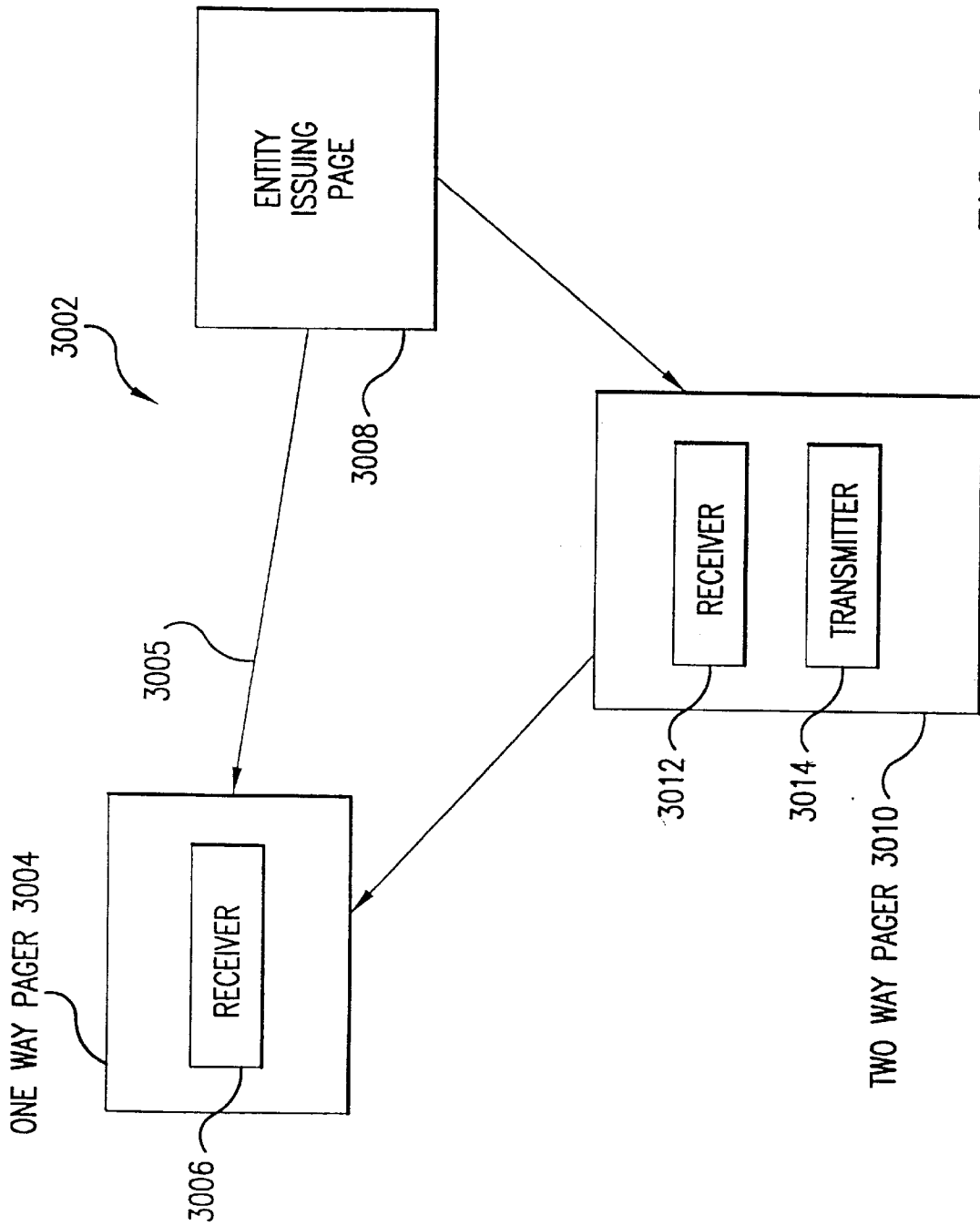


FIG. 30

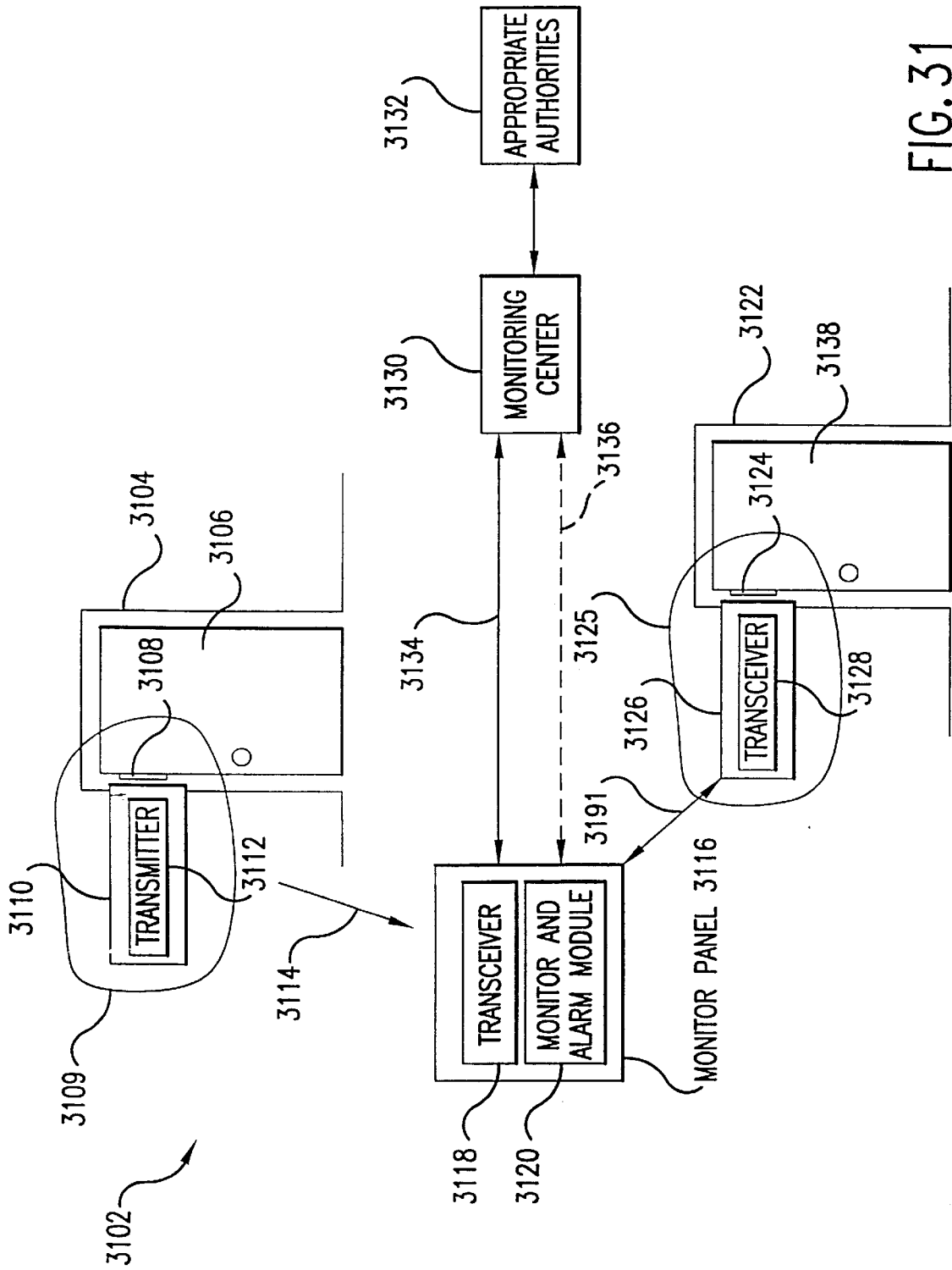


FIG. 31

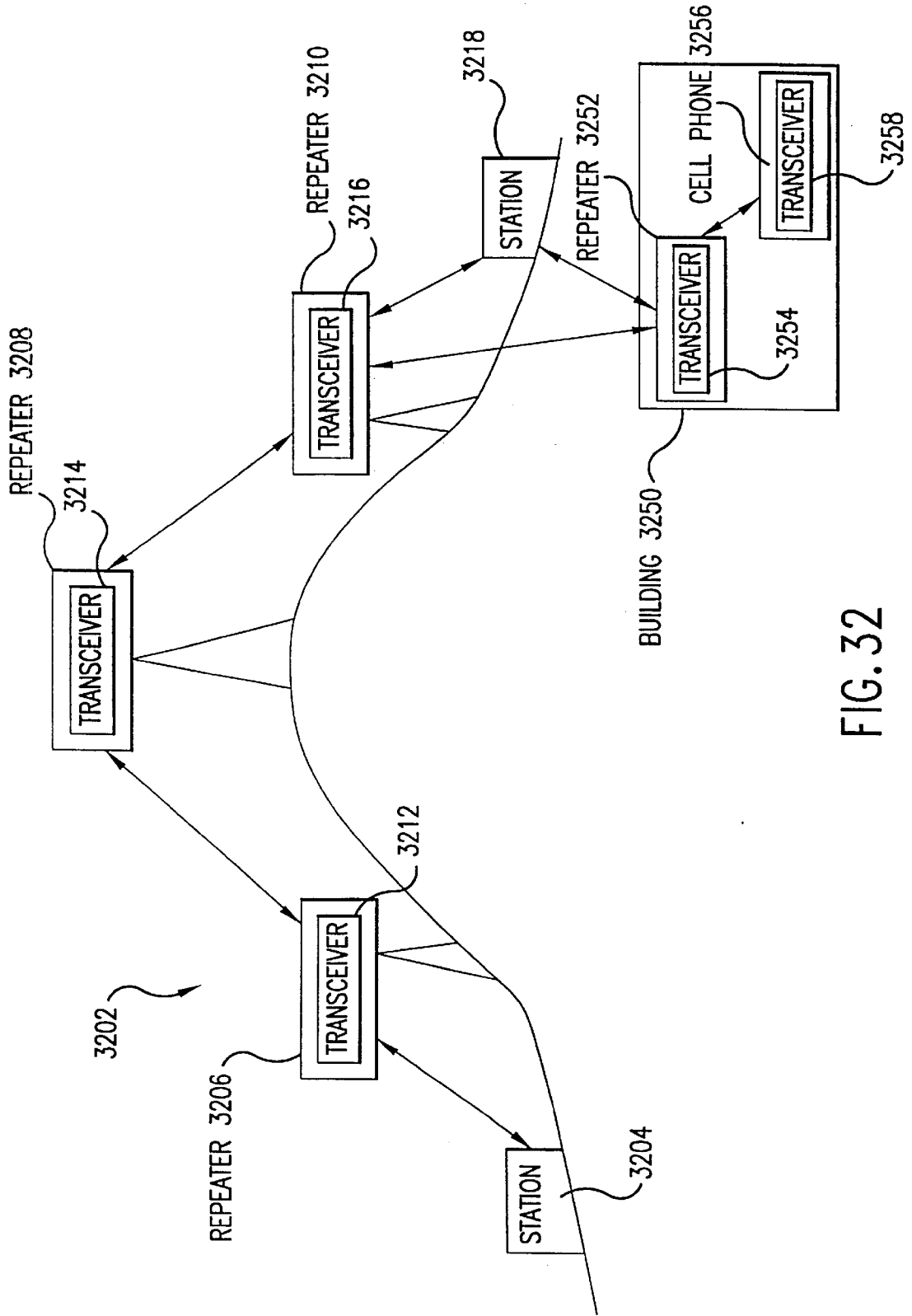


FIG. 32

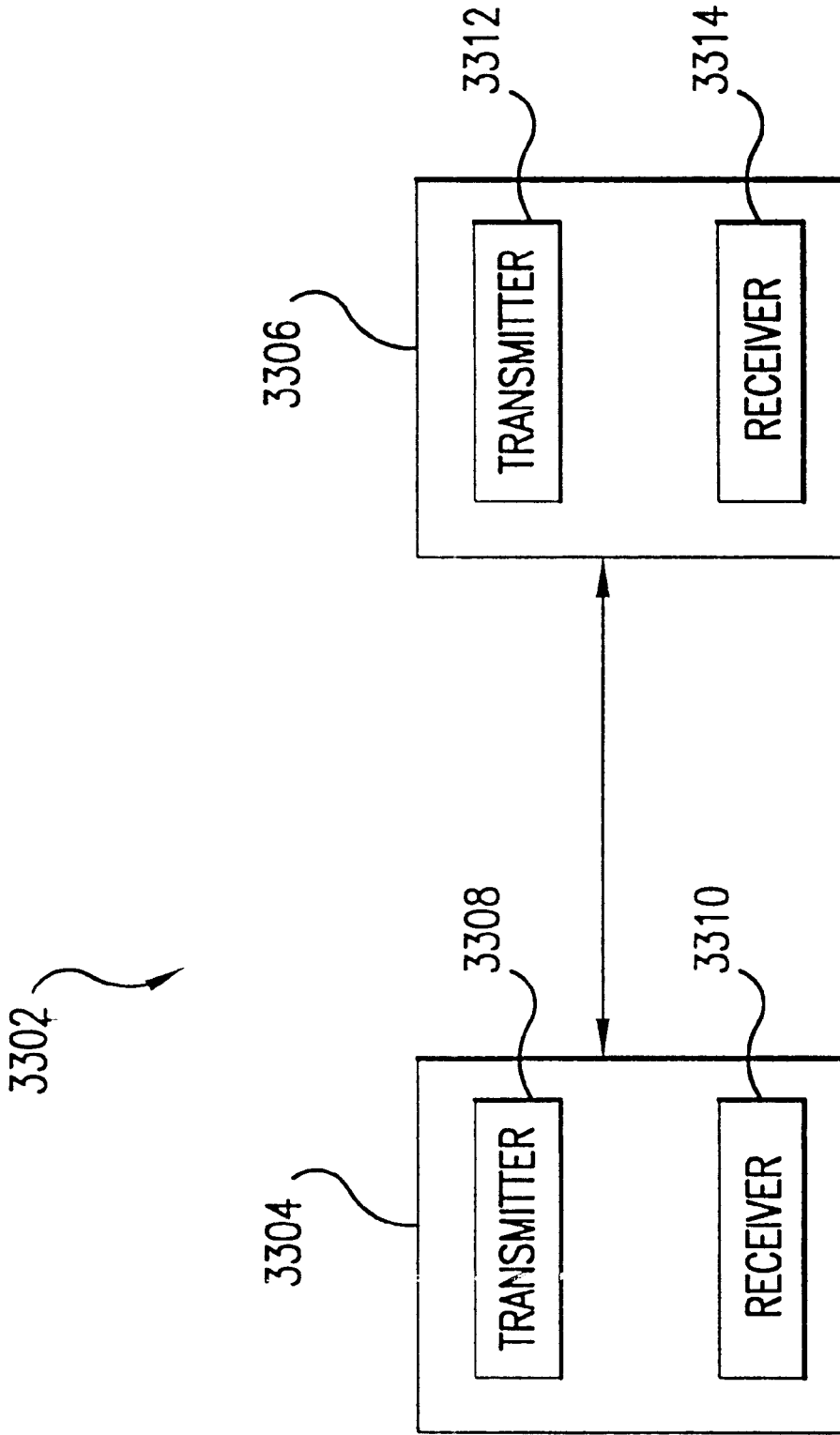


FIG. 33

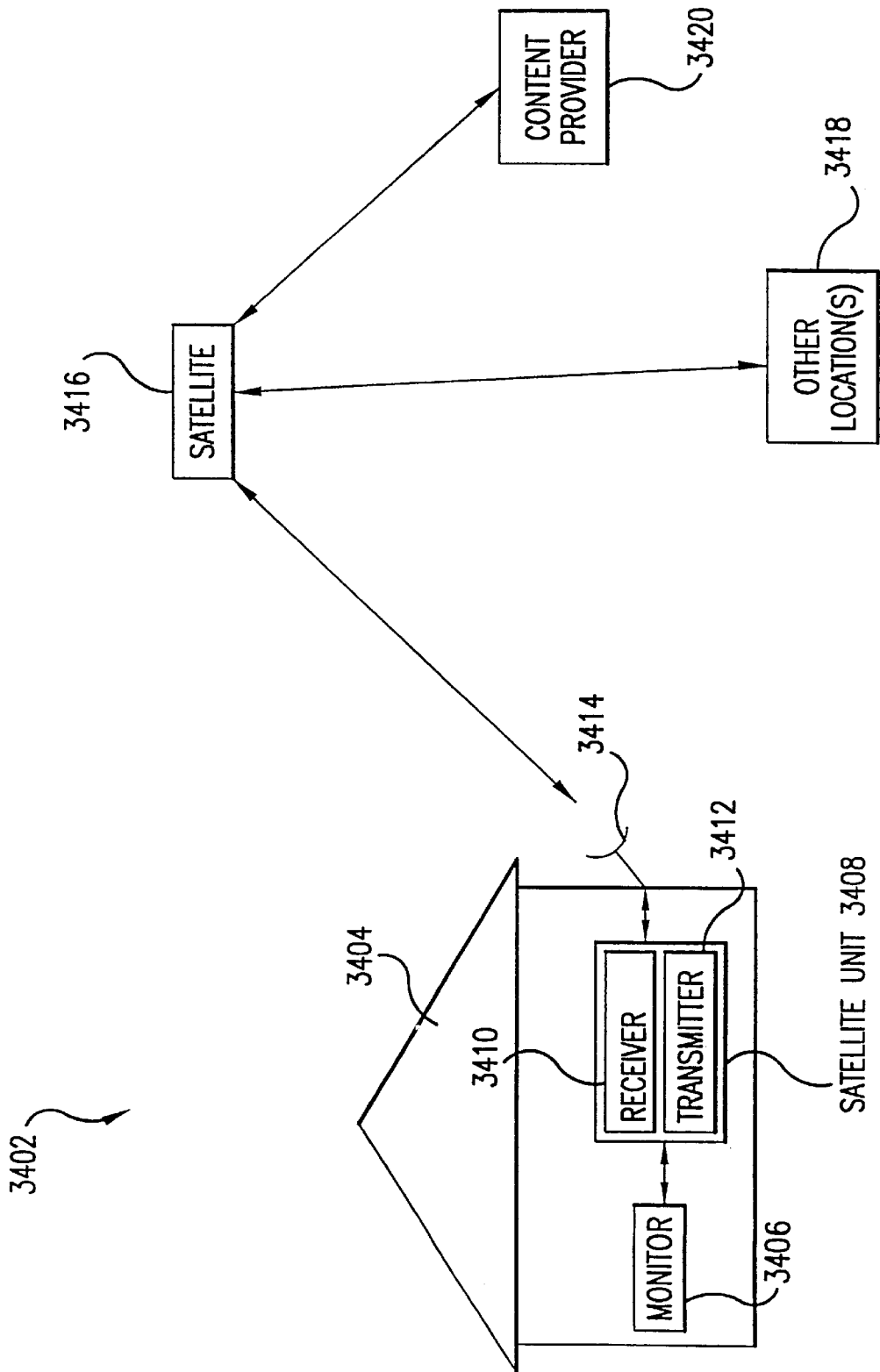


FIG. 34

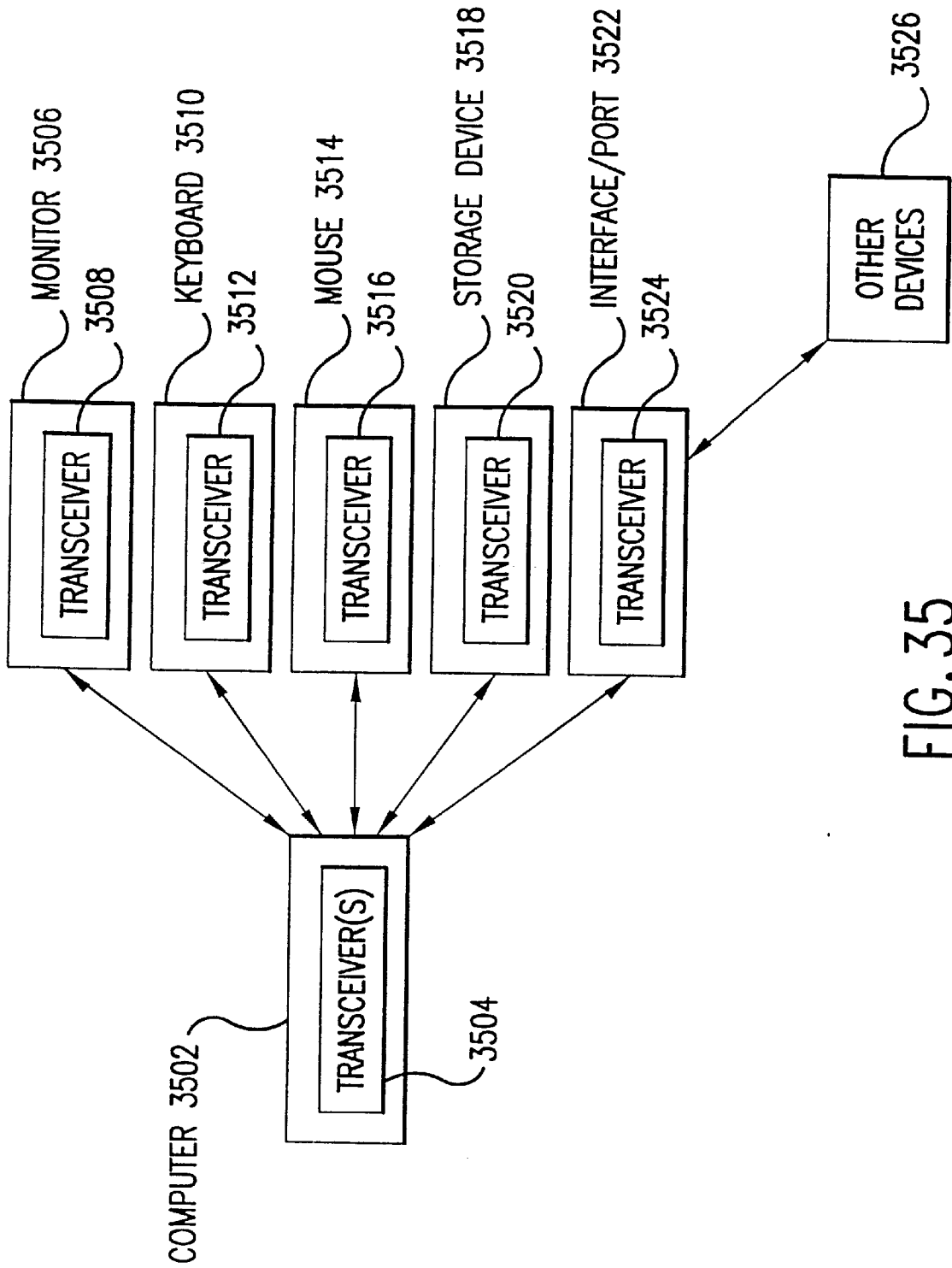


FIG. 35



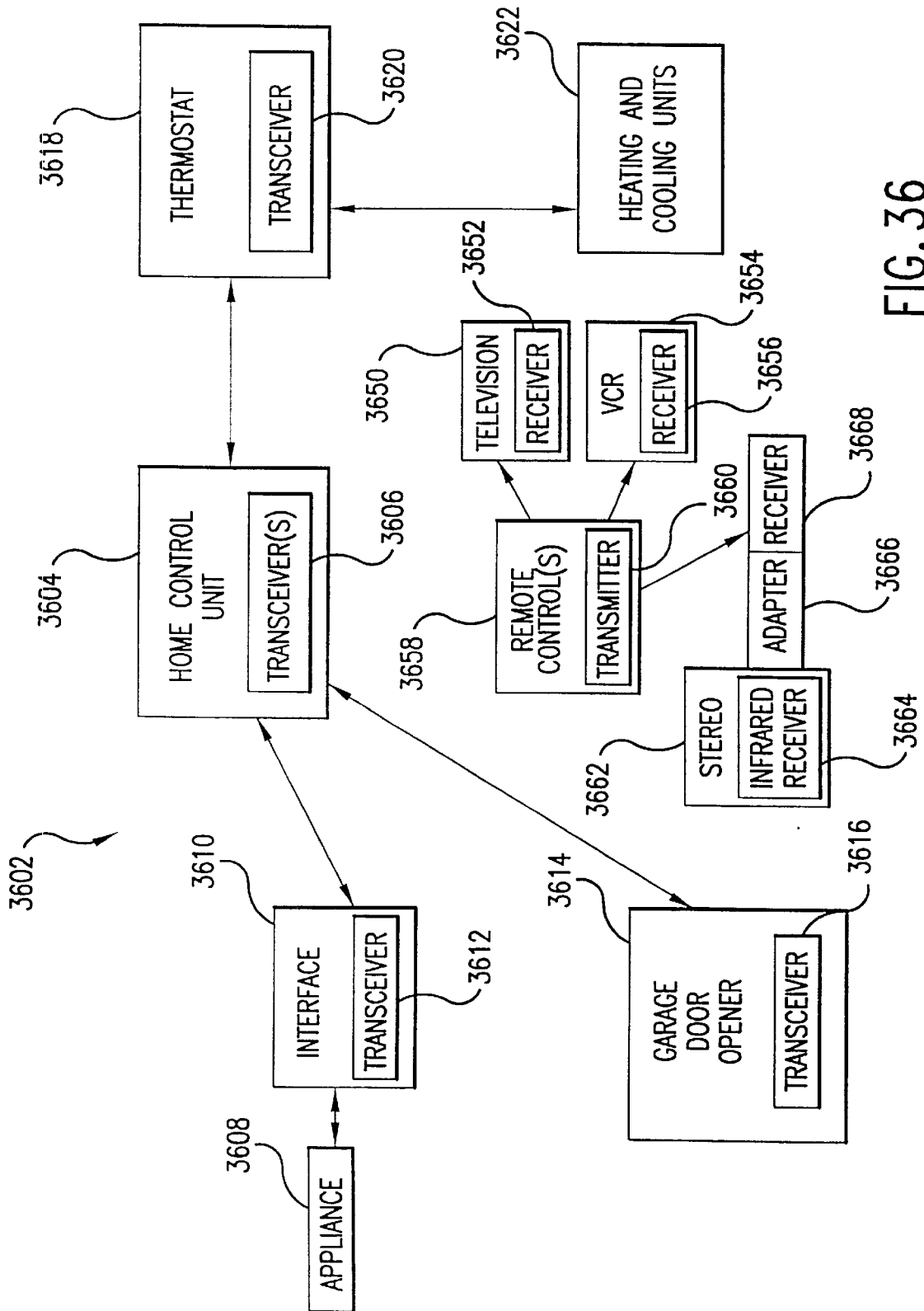


FIG. 36

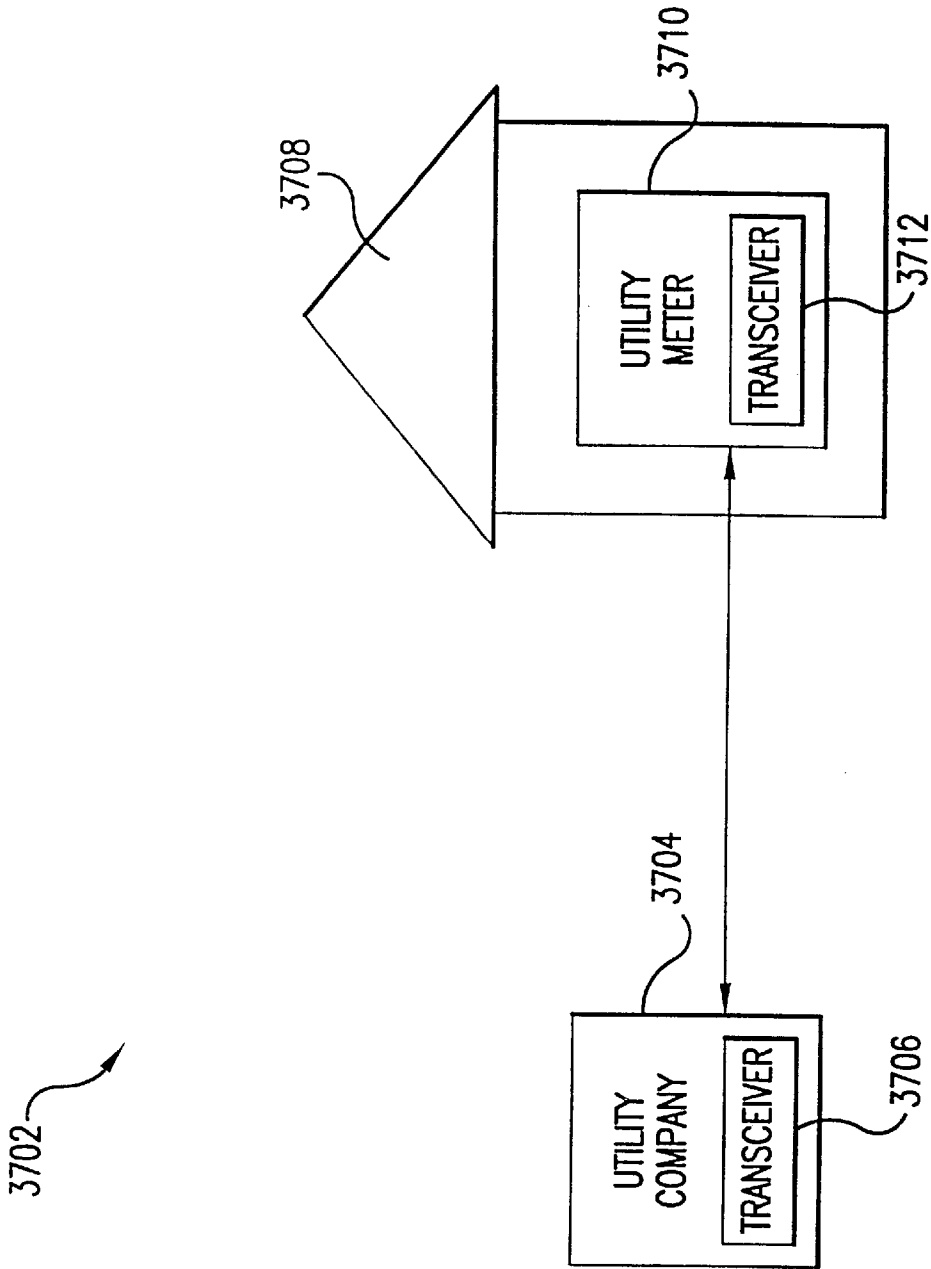


FIG. 37

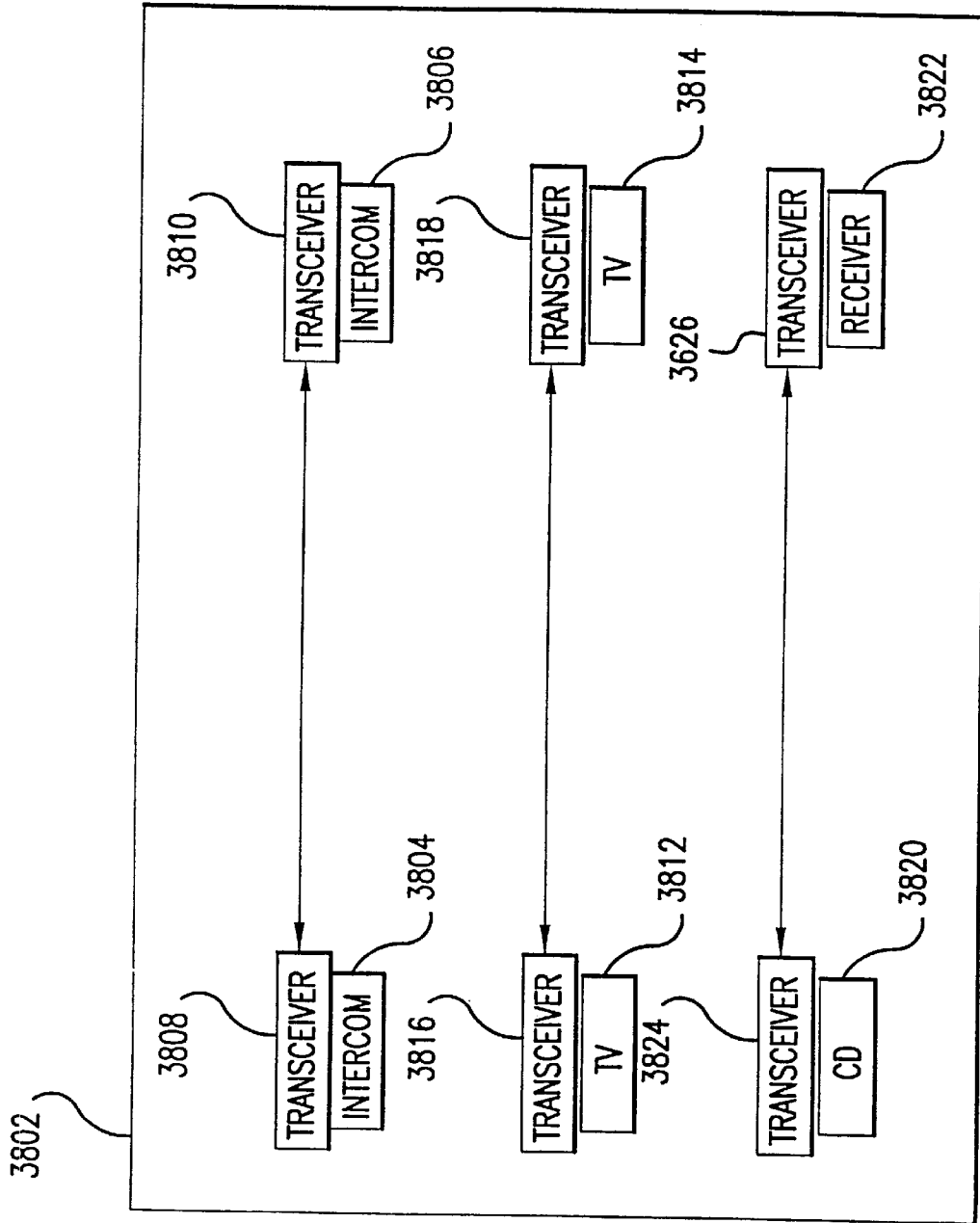


FIG. 38

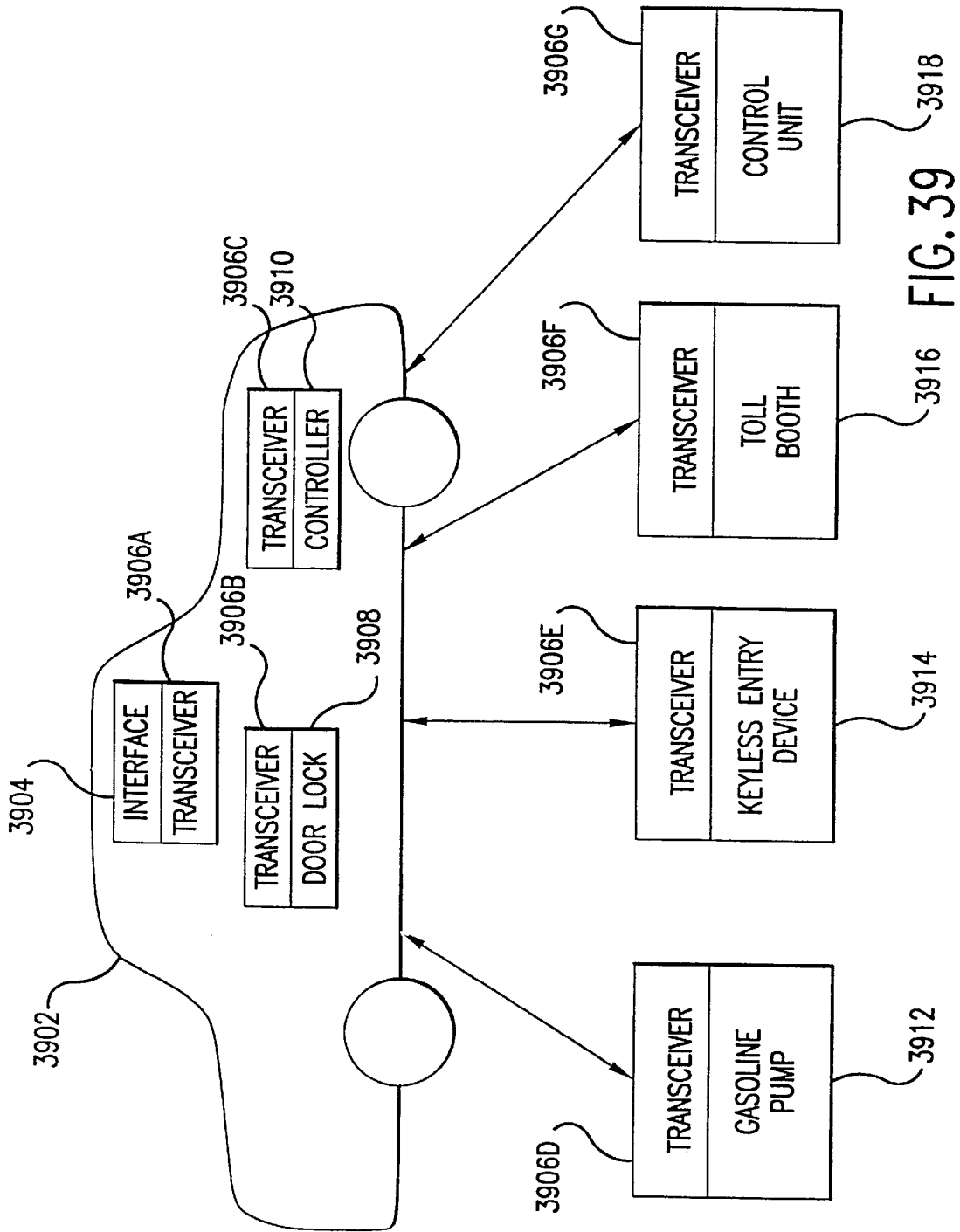


FIG. 39

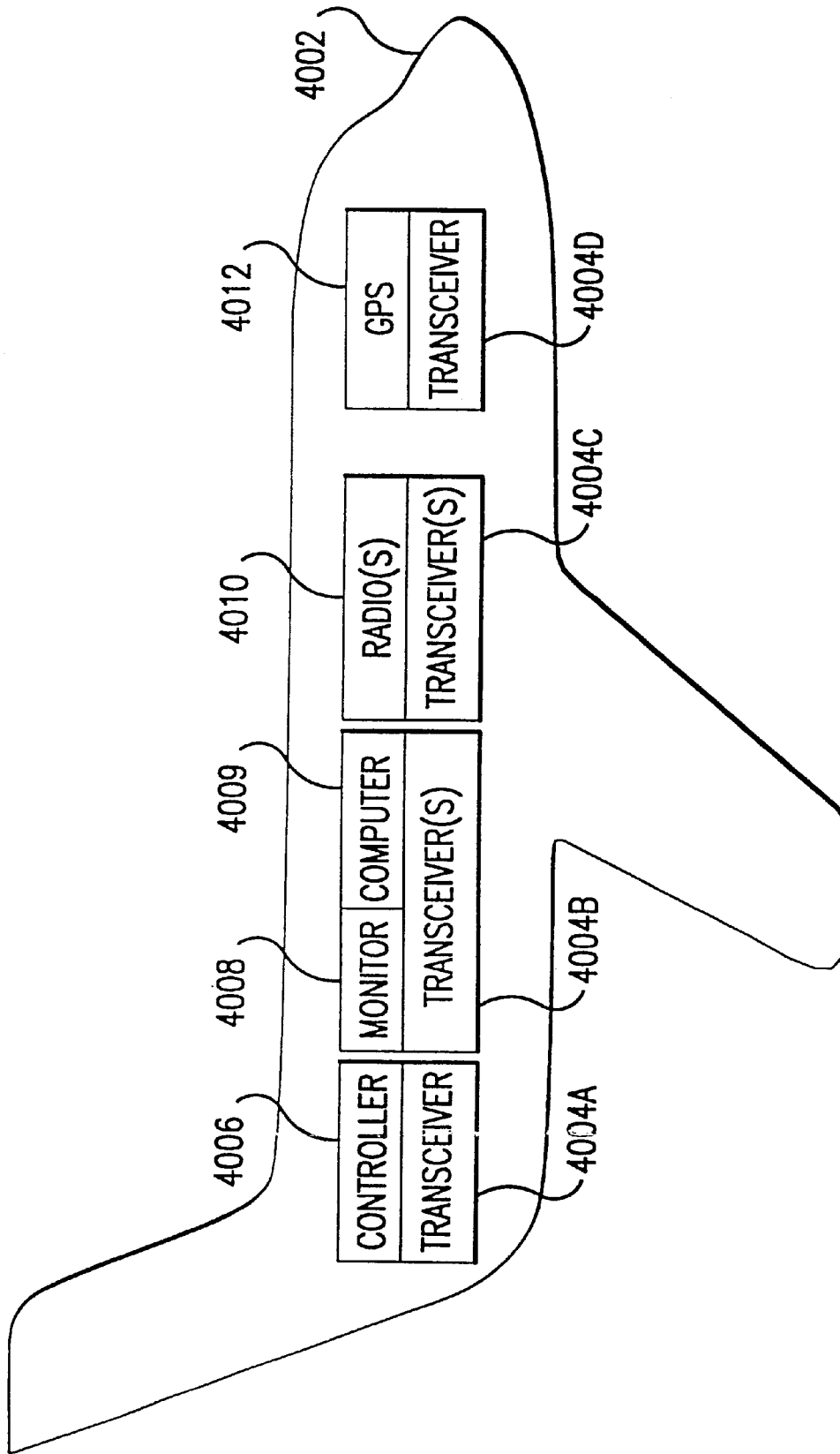


FIG. 40A

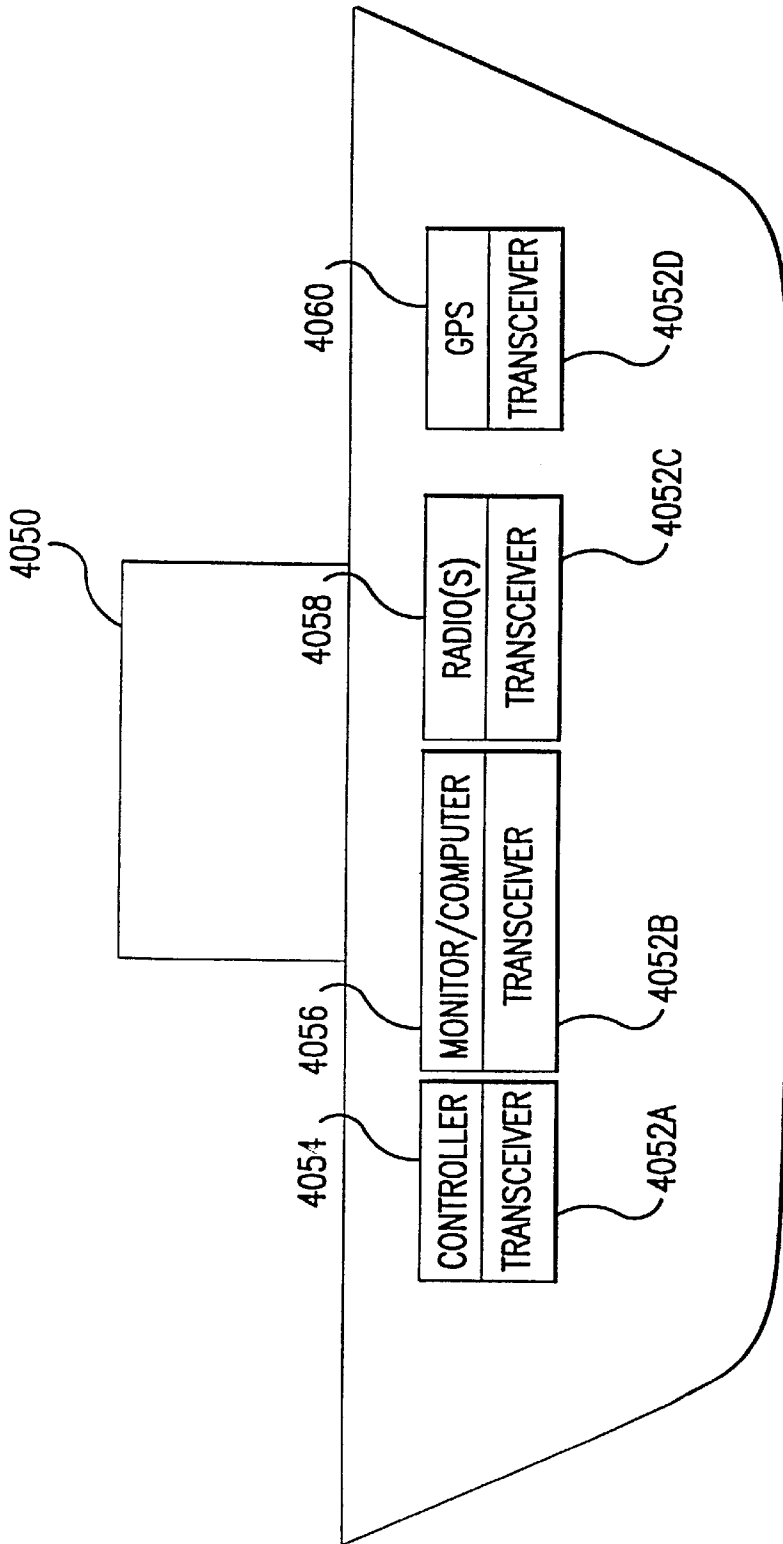


FIG. 40B

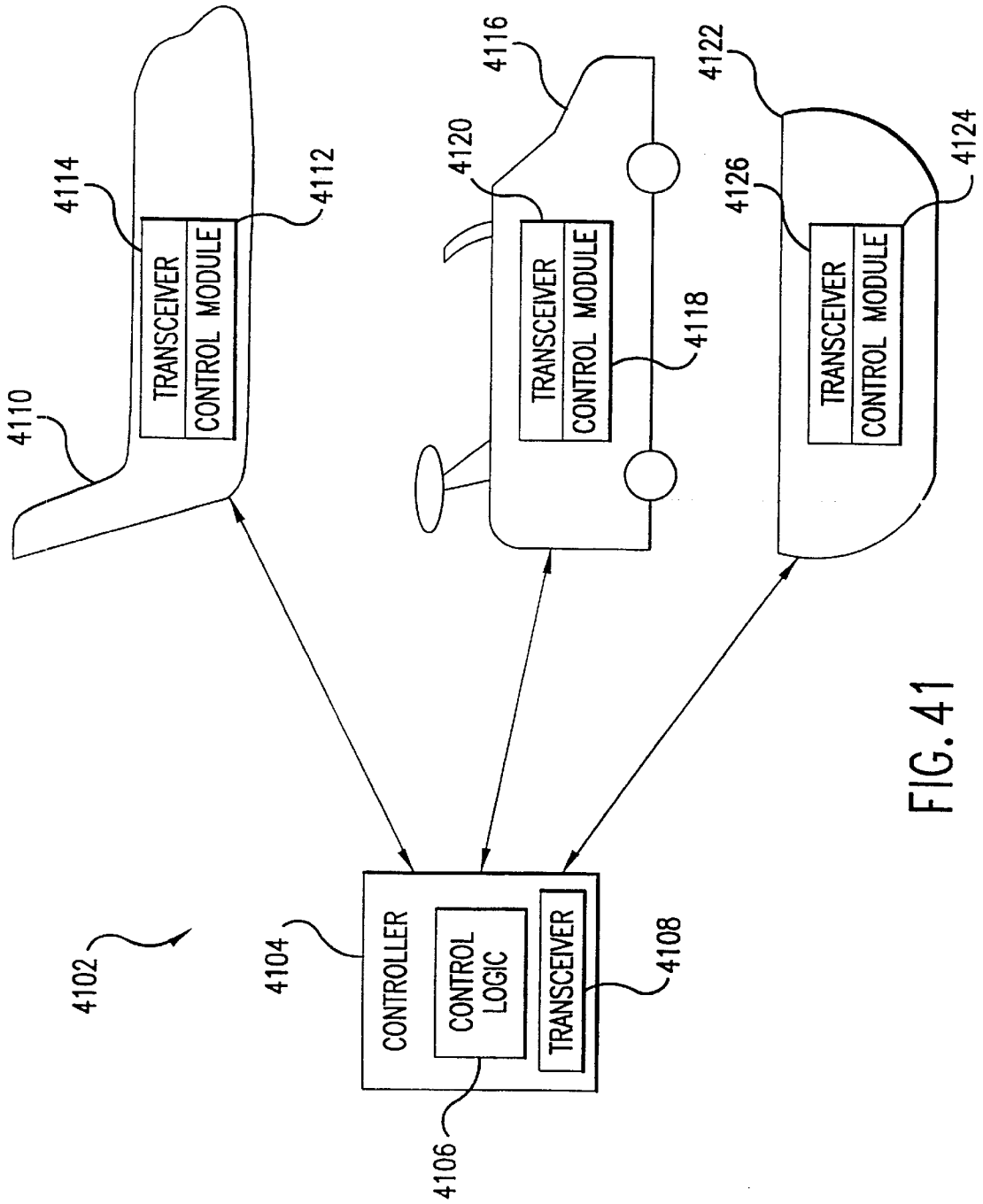


FIG. 41

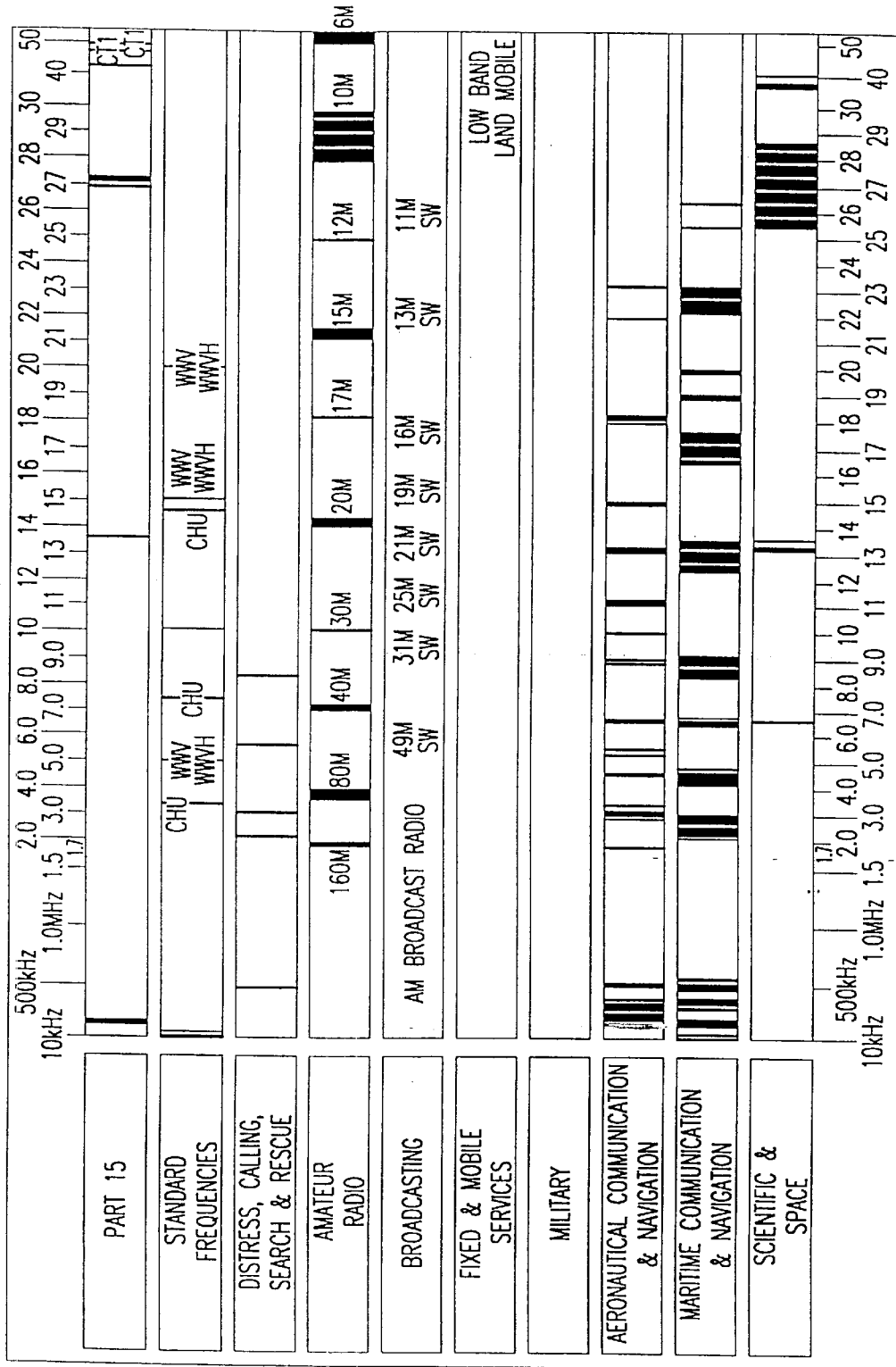


FIG. 42A



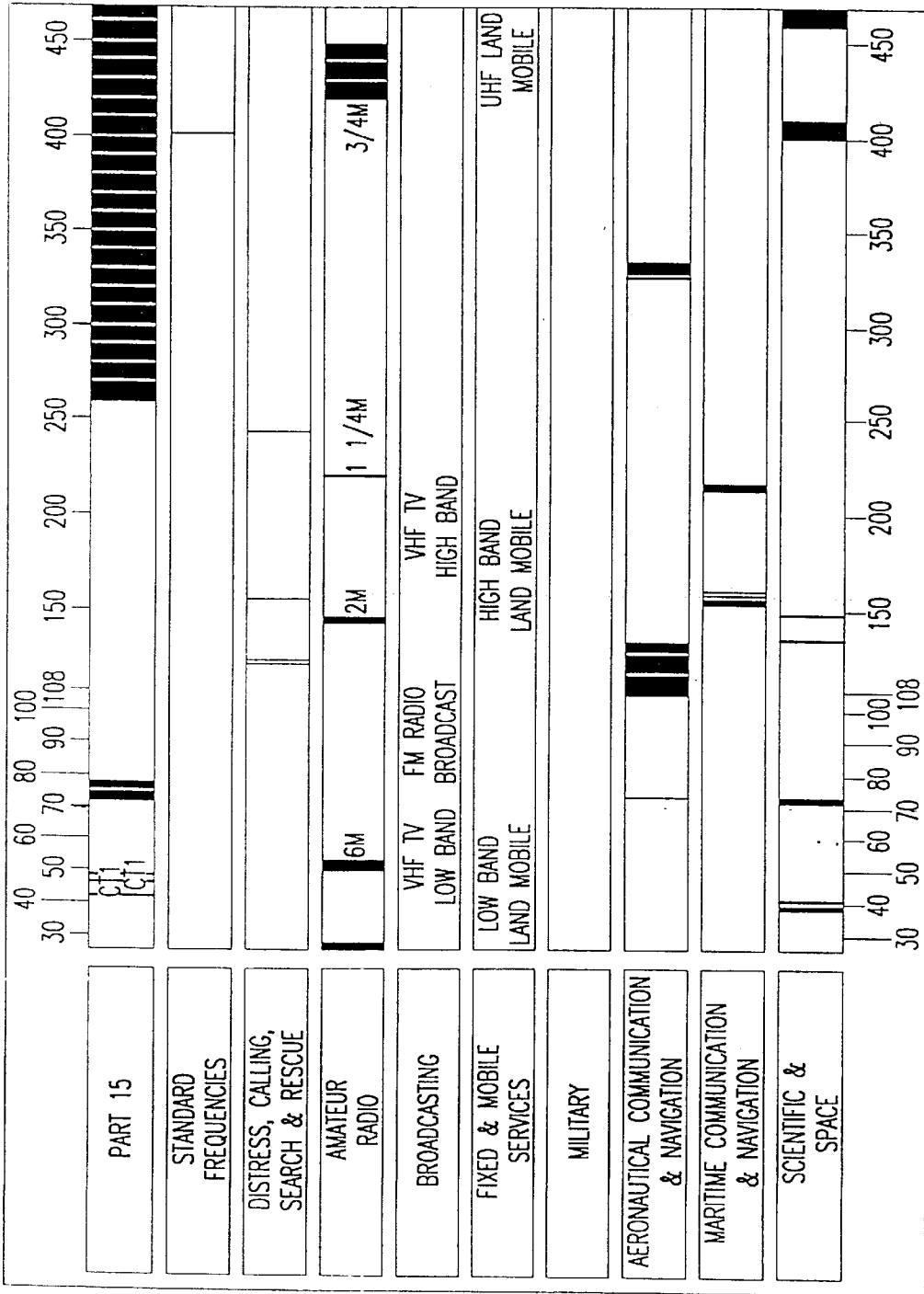


FIG. 42B

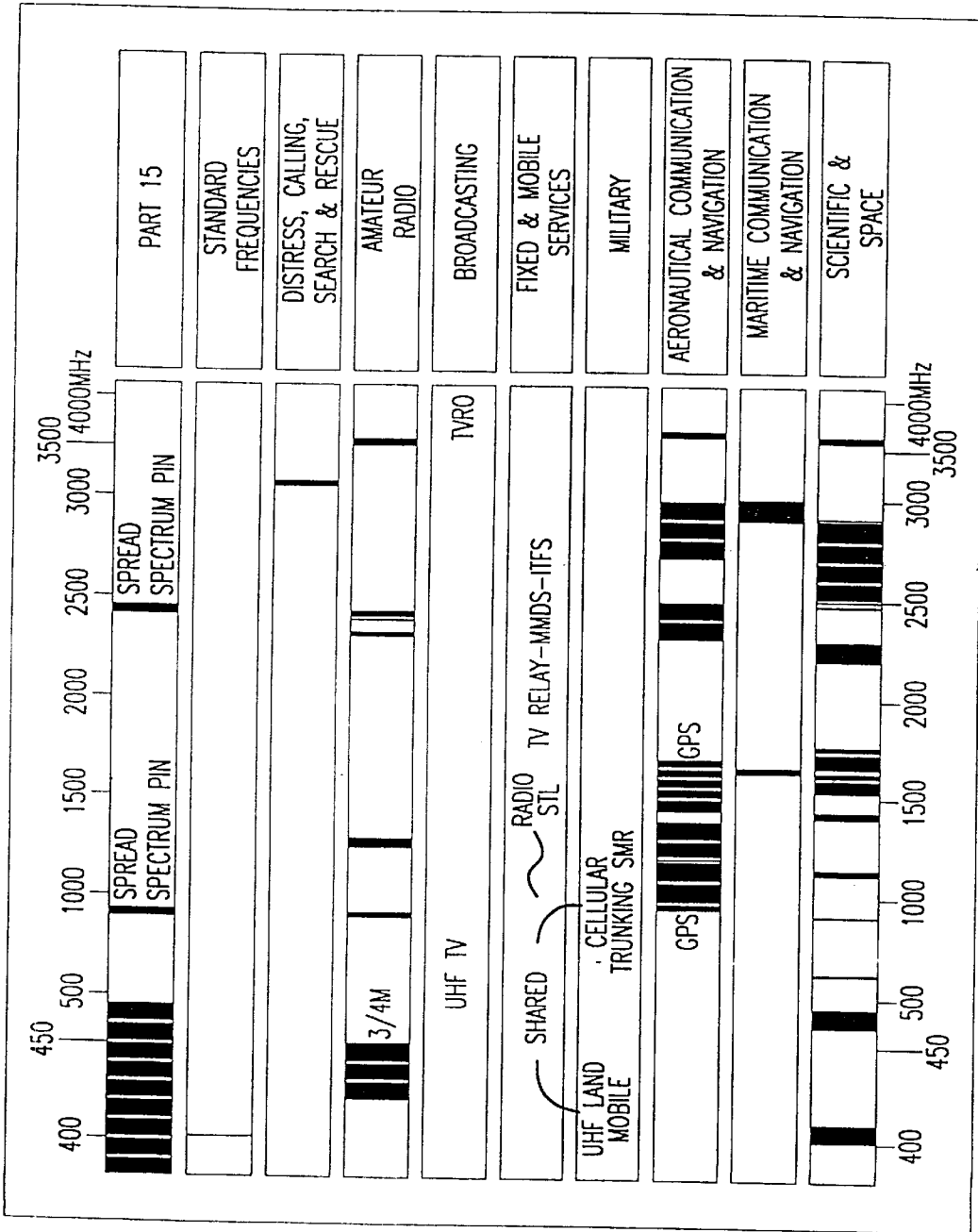


FIG. 42C

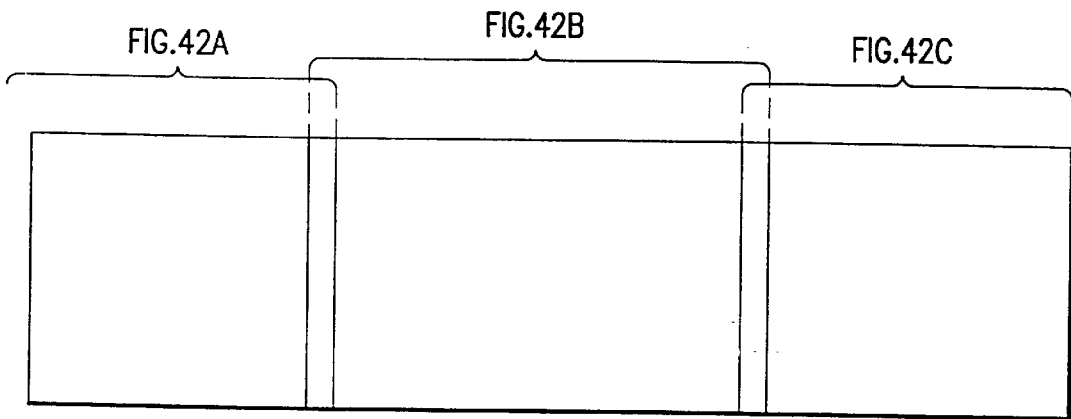


FIG. 42D

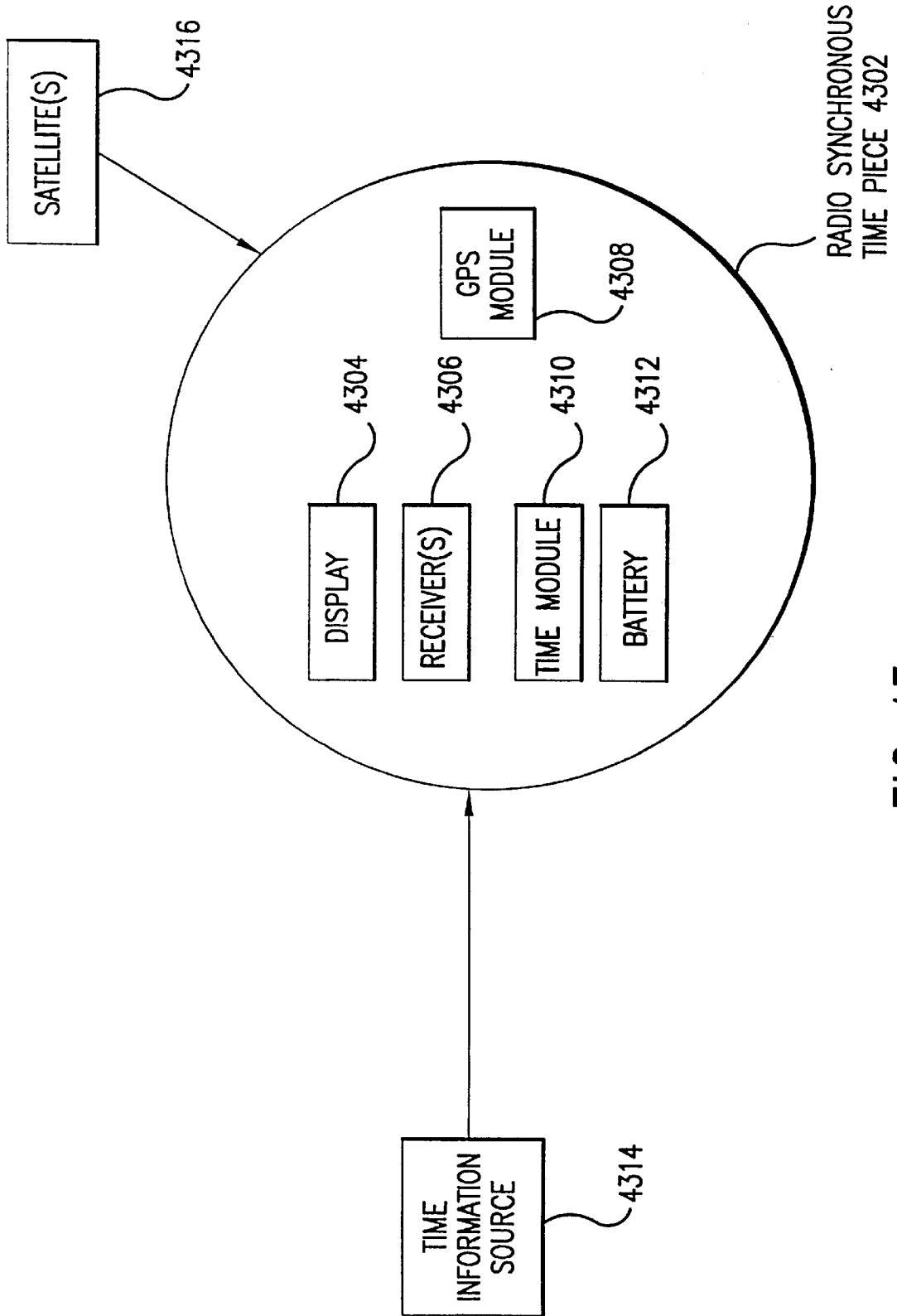


FIG. 43

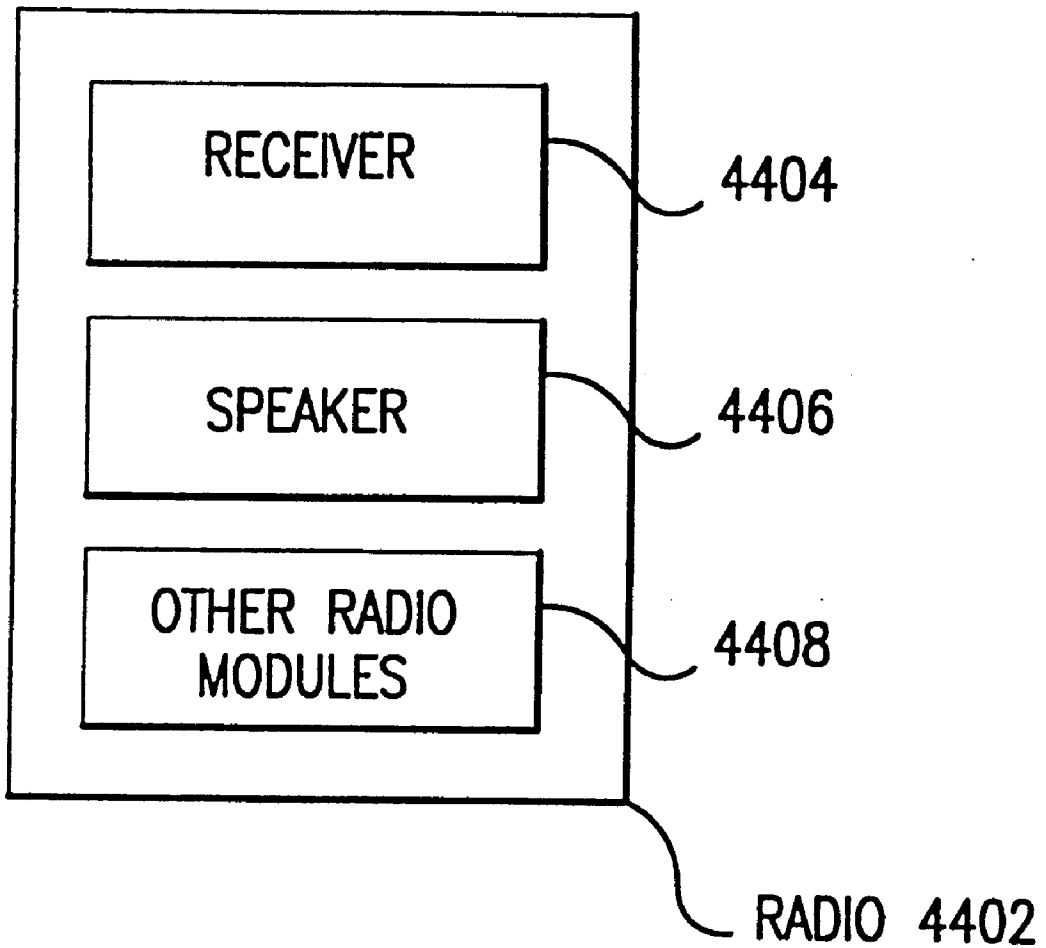


FIG. 44

## APPLICATIONS OF UNIVERSAL FREQUENCY TRANSLATION

The present application is a continuation-in-part of pending U.S. application "Universal Frequency Translation, and Applications of Same," Ser. No. 09/176,027, filed Oct. 21, 1998, incorporated herein by reference in its entirety, now abandoned.

### CROSS-REFERENCE TO OTHER APPLICATIONS

The following applications of common assignee are related to the present application, and are herein incorporated by reference in their entireties:

"Method and System for Down-Converting Electromagnetic Signals," Ser. No. 09/176,022, filed Oct. 21, 1998, now U.S. Pat. No. 6,061,551.

"Method and System for Frequency Up-Conversion," Ser. No. 09/176,154, filed Oct. 21, 1998, now U.S. Pat. No. 6,091,940.

"Method and System for Ensuring Reception of a Communications Signal," Ser. No. 09/176,415, filed Oct. 21, 1998, now U.S. Pat. No. 6,061,555.

"Integrated Frequency Translation And Selectivity," Ser. No. 09/175,966, filed Oct. 21, 1998, now U.S. Pat. No. 6,049,706.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention is generally related to frequency translation, and applications of same.

#### 2. Related Art

Various communication components exist for performing frequency down-conversion, frequency up-conversion, and filtering. Also, schemes exist for signal reception in the face of potential jamming signals.

### SUMMARY OF THE INVENTION

The present invention is related to frequency translation, and applications of same. Such applications include, but are not limited to, frequency down-conversion, frequency up-conversion, enhanced signal reception, unified down-conversion and filtering, and combinations and applications of same.

Further features and advantages of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings. The drawing in which an element first appears is typically indicated by the leftmost character (s) and/or digit(s) in the corresponding reference number.

### BRIEF DESCRIPTION OF THE FIGURES

The present invention will be described with reference to the accompanying drawings, wherein:

FIG. 1A is a block diagram of a universal frequency translation (UFT) module according to an embodiment of the invention;

FIG. 1B is a more detailed diagram of a universal frequency translation (UFT) module according to an embodiment of the invention;

FIG. 1C illustrates a UFT module used in a universal frequency down-conversion (UFD) module according to an embodiment of the invention;

FIG. 1D illustrates a UFT module used in a universal frequency up-conversion (UFU) module according to an embodiment of the invention;

FIG. 2 is a block diagram of a universal frequency translation (UFT) module according to an alternative embodiment of the invention;

FIG. 3 is a block diagram of a universal frequency up-conversion (UFU) module according to an embodiment of the invention;

FIG. 4 is a more detailed diagram of a universal frequency up-conversion (UFU) module according to an embodiment of the invention;

FIG. 5 is a block diagram of a universal frequency up-conversion (UFU) module according to an alternative embodiment of the invention;

FIGS. 6A-6I illustrate example waveforms used to describe the operation of the UFU module;

FIG. 7 illustrates a UFT module used in a receiver according to an embodiment of the invention;

FIG. 8 illustrates a UFT module used in a transmitter according to an embodiment of the invention;

FIG. 9 illustrates an environment comprising a transmitter and a receiver, each of which may be implemented using a UFT module of the invention;

FIG. 10 illustrates a transceiver according to an embodiment of the invention;

FIG. 11 illustrates a transceiver according to an alternative embodiment of the invention;

FIG. 12 illustrates an environment comprising a transmitter and a receiver, each of which may be implemented using enhanced signal reception (ESR) components of the invention;

FIG. 13 illustrates a UFT module used in a unified down-conversion and filtering (UDF) module according to an embodiment of the invention;

FIG. 14 illustrates an example receiver implemented using a UDF module according to an embodiment of the invention;

FIGS. 15A-15F illustrate example applications of the UDF module according to embodiments of the invention;

FIG. 16 illustrates an environment comprising a transmitter and a receiver, each of which may be implemented using enhanced signal reception (ESR) components of the invention, wherein the receiver may be further implemented using one or more UDF modules of the invention;

FIG. 17 illustrates a unified down-converting and filtering (UDF) module according to an embodiment of the invention;

FIG. 18 is a table of example values at nodes in the UDF module of FIG. 17;

FIG. 19 is a detailed diagram of an example UDF module according to an embodiment of the invention;

FIGS. 20A and 20A-1 are example aliasing modules according to embodiments of the invention;

FIGS. 20B-20F are example waveforms used to describe the operation of the aliasing modules of FIGS. 20A and 20A-1;

FIG. 21 illustrates an enhanced signal reception system according to an embodiment of the invention;

FIGS. 22A-22F are example waveforms used to describe the system of FIG. 21;

FIG. 23A illustrates an example transmitter in an enhanced signal reception system according to an embodiment of the invention;

FIGS. 23B and 23C are example waveforms used to further describe the enhanced signal reception system according to an embodiment of the invention;

FIG. 23D illustrates another example transmitter in an enhanced signal reception system according to an embodiment of the invention;

FIGS. 23E and 23F are example waveforms used to further describe the enhanced signal reception system according to an embodiment of the invention;

FIG. 24A illustrates an example receiver in an enhanced signal reception system according to an embodiment of the invention;

FIGS. 24B–24J are example waveforms used to further describe the enhanced signal reception system according to an embodiment of the invention;

FIG. 25 illustrates an environment comprising telephones and base stations according to an embodiment of the invention;

FIG. 26 illustrates a positioning unit according to an embodiment of the invention;

FIGS. 27 and 28 illustrate communication networks according to embodiments of the invention;

FIGS. 29 and 30 illustrate pagers according to embodiments of the invention;

FIG. 31 illustrates a security system according to an embodiment of the invention;

FIG. 32 illustrates a repeater according to an embodiment of the invention;

FIG. 33 illustrates mobile radios according to an embodiment of the invention;

FIG. 34 illustrates an environment involving satellite communications according to an embodiment of the invention;

FIG. 35 illustrates a computer and its peripherals according to an embodiment of the invention;

FIGS. 36–38 illustrate home control devices according to embodiments of the invention;

FIG. 39 illustrates an example automobile according to an embodiment of the invention;

FIG. 40A illustrates an example aircraft according to an embodiment of the invention;

FIG. 40B illustrates an example boat according to an embodiment of the invention;

FIG. 41 illustrates radio controlled devices according to an embodiment of the invention;

FIGS. 42A–42D illustrate example frequency bands operable with embodiments of the invention, where FIG. 42D illustrates the orientation of FIGS. 42A–42C (some overlap is shown in FIGS. 42A–42C for illustrative purposes);

FIG. 43 illustrates an example radio synchronous watch according to an embodiment of the invention; and

FIG. 44 illustrates an example radio according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Table of Contents

Universal Frequency Translation  
 Frequency Down-conversion  
 Frequency Up-conversion  
 Enhanced Signal Reception

Unified Down-conversion and Filtering

Example Application Embodiments of the Invention

Telephones  
 Base Stations  
 Positioning  
 Data Communication  
 Pagers  
 Security  
 Repeaters  
 Mobile Radios  
 Satellite Up/Down Links  
 Command and Control  
     PC Peripherals  
     Building/Home Functions  
     Automotive Controls  
     Aircraft Controls  
     Maritime Controls  
 Radio Control  
 Radio Synchronous Watch  
 Other Example Applications  
 Applications Involving Enhanced Signal Reception  
 Applications Involving Unified Down-conversion and Filtering

Conclusion

Universal Frequency Translation

The present invention is related to frequency translation, and applications of same. Such applications include, but are not limited to, frequency down-conversion, frequency up-conversion, enhanced signal reception, unified down-conversion and filtering, and combinations and applications of same.

FIG. 1A illustrates a universal frequency translation (UFT) module 102 according to embodiments of the invention. (The UFT module is also sometimes called a universal frequency translator, or a universal translator.)

As indicated by the example of FIG. 1A, some embodiments of the UFT module 102 include three ports (nodes), designated in FIG. 1A as Port 1, Port 2, and Port 3. Other UFT embodiments include other than three ports.

Generally, the UFT module 102 (perhaps in combination with other components) operates to generate an output signal from an input signal, where the frequency of the output signal differs from the frequency of the input signal. In other words, the UFT module 102 (and perhaps other components) operates to generate the output signal from the input signal by translating the frequency (and perhaps other characteristics) of the input signal to the frequency (and perhaps other characteristics) of the output signal.

An example embodiment of the UFT module 103 is generally illustrated in FIG. 1B. Generally, the UFT module 103 includes a switch 106 controlled by a control signal 108. The switch 106 is said to be a controlled switch.

As noted above, some UFT embodiments include other than three ports. For example, and without limitation, FIG. 2 illustrates an example UFT module 202. The example UFT module 202 includes a diode 204 having two ports, designated as Port 1 and Port 2/3. This embodiment does not include a third port, as indicated by the dotted line around the “Port 3” label.

The UFT module is a very powerful and flexible device. Its flexibility is illustrated, in part, by the wide range of applications in which it can be used. Its power is illustrated, in part, by the usefulness and performance of such applications.

For example, a UFT module 115 can be used in a universal frequency down-conversion (UFD) module 114, an example of which is shown in FIG. 1C. In this capacity,

the UFT module **115** frequency down-converts an input signal to an output signal.

As another example, as shown in FIG. 1D, a UFT module **117** can be used in a universal frequency up-conversion (UFU) module **116**. In this capacity, the UFT module **117** frequency up-converts an input signal to an output signal.

These and other applications of the UFT module are described below. Additional applications of the UFT module will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. In some applications, the UFT module is a required component. In other applications, the UFT module is an optional component.

#### Frequency Down-conversion

The present invention is directed to systems and methods of universal frequency down-conversion, and applications of same.

In particular, the following discussion describes down-converting using a Universal Frequency Translation Module. The down-conversion of an EM signal by aliasing the EM signal at an aliasing rate is fully described in co-pending U.S. patent application entitled "Method and System for Down-Converting Electromagnetic Signals," Ser. No. 09/176,022, filed Oct. 21, 1998, the full disclosure of which is incorporated herein by reference. A relevant portion of the above mentioned patent application is summarized below to describe down-converting an input signal to produce a down-converted signal that exists at a lower frequency or a baseband signal.

FIG. 20A illustrates an aliasing module **2000** for down-conversion using a universal frequency translation (UFT) module **2002** which down-converts an EM input signal **2004**. In particular embodiments, aliasing module **2000** includes a switch **2008** and a capacitor **2010**. The electronic alignment of the circuit components is flexible. That is, in one implementation, the switch **2008** is in series with input signal **2004** and capacitor **2010** is shunted to ground (although it may be other than ground in configurations such as differential mode). In a second implementation (see FIG. 20A-1), the capacitor **2010** is in series with the input signal **2004** and the switch **2008** is shunted to ground (although it maybe other than ground in configurations such as differential mode). Aliasing module **2000** with UFT module **2002** can be easily tailored to down-convert a wide variety of electromagnetic signals using aliasing frequencies that are well below the frequencies of the EM input signal **2004**.

In one implementation, aliasing module **2000** down-converts the input signal **2004** to an intermediate frequency (IF) signal. In another implementation, the aliasing module **2000** down-converts the input signal **2004** to a demodulated baseband signal. In yet another implementation, the input signal **2004** is a frequency modulated (FM) signal, and the aliasing module **2000** down-converts it to a non-FM signal, such as a phase modulated (PM) signal or an amplitude modulated (AM) signal. Each of the above implementations is described below.

In an embodiment, the control signal **2006** includes a train of pulses that repeat at an aliasing rate that is equal to, or less than, twice the frequency of the input signal **2004**. In this embodiment, the control signal **2006** is referred to herein as an aliasing signal because it is below the Nyquist rate for the frequency of the input signal **2004**. Preferably, the frequency of control signal **2006** is much less than the input signal **2004**.

A train of pulses **2018** as shown in FIG. 20D controls the switch **2008** to alias the input signal **2004** with the control signal **2006** to generate a down-converted output signal

**2012**. More specifically, in an embodiment, switch **2008** closes on a first edge of each pulse **2020** of FIG. 20D and opens on a second edge of each pulse. When the switch **2008** is closed, the input signal **2004** is coupled to the capacitor **2010**, and charge is transferred from the input signal to the capacitor **2010**. The charge stored during successive pulses forms down-converted output signal **2012**.

Exemplary waveforms are shown in FIGS. 20B–20F.

FIG. 20B illustrates an analog amplitude modulated (AM) carrier signal **2014** that is an example of input signal **2004**. For illustrative purposes, in FIG. 20C, an analog AM carrier signal portion **2016** illustrates a portion of the analog AM carrier signal **2014** on an expanded time scale. The analog AM carrier signal portion **2016** illustrates the analog AM carrier signal **2014** from time  $t_0$  to time  $t_1$ .

FIG. 20D illustrates an exemplary aliasing signal **2018** that is an example of control signal **2006**. Aliasing signal **2018** is on approximately the same time scale as the analog AM carrier signal portion **2016**. In the example shown in FIG. 20D, the aliasing signal **2018** includes a train of pulses **2020** having negligible apertures that tend towards zero (the invention is not limited to this embodiment, as discussed below). The pulse aperture may also be referred to as the pulse width as will be understood by those skilled in the art(s). The pulses **2020** repeat at an aliasing rate, or pulse repetition rate of aliasing signal **2018**. The aliasing rate is determined as described below, and further described in co-pending U.S. patent application entitled "Method and System for Down-converting Electromagnetic Signals," application Ser. No. 09/176,022, Attorney Docket Number 1744.0010000.

As noted above, the train of pulses **2020** (i.e., control signal **2006**) control the switch **2008** to alias the analog AM carrier signal **2016** (i.e., input signal **2004**) at the aliasing rate of the aliasing signal **2018**. Specifically, in this embodiment, the switch **2008** closes on a first edge of each pulse and opens on a second edge of each pulse. When the switch **2008** is closed, input signal **2004** is coupled to the capacitor **2010**, and charge is transferred from the input signal **2004** to the capacitor **2010**. The charge transferred during a pulse is referred to herein as an under-sample. Exemplary under-samples **2022** form down-converted signal portion **2024** (FIG. 20E) that corresponds to the analog AM carrier signal portion **2016** (FIG. 20C) and the train of pulses **2020** (FIG. 20D). The charge stored during successive under-samples of AM carrier signal **2014** form the down-converted signal **2024** (FIG. 20E) that is an example of down-converted output signal **2012** (FIG. 20A). In FIG. 20F, a demodulated baseband signal **2026** represents the demodulated baseband signal **2024** after filtering on a compressed time scale. As illustrated, down-converted signal **2026** has substantially the same "amplitude envelope" as AM carrier signal **2014**. Therefore, FIGS. 20B–20F illustrate down-conversion of AM carrier signal **2014**.

The waveforms shown in FIGS. 20B–20F are discussed herein for illustrative purposes only, and are not limiting. Additional exemplary time domain and frequency domain drawings, and exemplary methods and systems of the invention relating thereto, are disclosed in co-pending U.S. patent application entitled "Method and System for Down-converting Electromagnetic Signals," application Ser. No. 09/176,022, Attorney Docket Number 1744.0010000.

The aliasing rate of control signal **2006** determines whether the input signal **2004** is down-converted to an IF signal, down-converted to a demodulated baseband signal, or down-converted from an FM signal to a PM or an AM signal. Generally, relationships between the input signal



**2004**, the aliasing rate of the control signal **2006**, and the down-converted output signal **2012** are illustrated below:

$$\text{(Freq. of input signal 2004)} = n \cdot \text{(Freq. of control signal 2006)} \pm \text{(Freq. of down-converted output signal 2012)}$$

For the examples contained herein, only the “+” condition will be discussed. The value of  $n$  represents a harmonic or sub-harmonic of input signal **2004** (e.g.,  $n=0.5, 1, 2, 3, \dots$ ).

When the aliasing rate of control signal **2006** is off-set from the frequency of input signal **2004**, or off-set from a harmonic or sub-harmonic thereof, input signal **2004** is down-converted to an IF signal. This is because the under-sampling pulses occur at different phases of subsequent cycles of input signal **2004**. As a result, the under-samples form a lower frequency oscillating pattern. If the input signal **2004** includes lower frequency changes, such as amplitude, frequency, phase, etc., or any combination thereof, the charge stored during associated under-samples reflects the lower frequency changes, resulting in similar changes on the down-converted IF signal. For example, to down-convert a 901 MHz input signal to a 1 MHz IF signal, the frequency of the control signal **2006** would be calculated as follows:

$$\text{(Freq}_{input} - \text{Freq}_{IF})/n = \text{Freq}_{control} (901 \text{ MHz} - 1 \text{ MHz})/n = 900/n$$

For  $n=0.5, 1, 2, 3, 4$ , etc., the frequency of the control signal **2006** would be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc.

Exemplary time domain and frequency domain drawings, illustrating down-conversion of analog and digital AM, PM and FM signals to IF signals, and exemplary methods and systems thereof, are disclosed in co-pending U.S. patent application entitled “Method and System for Down-converting Electromagnetic Signals,” application Ser. No. 09/176,022, Attorney Docket Number 1744.0010000.

Alternatively, when the aliasing rate of the control signal **2006** is substantially equal to the frequency of the input signal **2004**, or substantially equal to a harmonic or sub-harmonic thereof, input signal **2004** is directly down-converted to a demodulated baseband signal. This is because, without modulation, the under-sampling pulses occur at the same point of subsequent cycles of the input signal **2004**. As a result, the under-samples form a constant output baseband signal. If the input signal **2004** includes lower frequency changes, such as amplitude, frequency, phase, etc., or any combination thereof, the charge stored during associated under-samples reflects the lower frequency changes, resulting in similar changes on the demodulated baseband signal. For example, to directly down-convert a 900 MHz input signal to a demodulated baseband signal (i.e., zero IF), the frequency of the control signal **2006** would be calculated as follows:

$$\text{(Freq}_{input} - \text{Freq}_{IF})/n = \text{Freq}_{control} (900 \text{ MHz} - 0 \text{ MHz})/n = 900 \text{ MHz}/n$$

For  $n=0.5, 1, 2, 3, 4$ , etc., the frequency of the control signal **2006** should be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc.

Exemplary time domain and frequency domain drawings, illustrating direct down-conversion of analog and digital AM and PM signals to demodulated baseband signals, and exemplary methods and systems thereof, are disclosed in the co-pending U.S. patent application entitled “Method and System for Down-converting Electromagnetic Signals,” application Ser. No. 09/176,022, Attorney Docket Number 1744.0010000.

Alternatively, to down-convert an input FM signal to a non-FM signal, a frequency within the FM bandwidth must

be down-converted to baseband (i.e., zero IF). As an example, to down-convert a frequency shift keying (FSK) signal (a sub-set of FM) to a phase shift keying (PSK) signal (a subset of PM), the mid-point between a lower frequency  $F_1$  and an upper frequency  $F_2$  (that is,  $[(F_1 + F_2) \div 2]$ ) of the FSK signal is down-converted to zero IF. For example, to down-convert an FSK signal having  $F_1$  equal to 899 MHz and  $F_2$  equal to 901 MHz, to a PSK signal, the aliasing rate of the control signal **2006** would be calculated as follows:

$$\begin{aligned} \text{Frequency of the input} &= (F_1 + F_2) \div 2 \\ &= (899 \text{ MHz} + 901 \text{ MHz}) \div 2 \\ &= 900 \text{ MHz} \end{aligned}$$

Frequency of the down-converted signal=0 (i.e., baseband)

$$\text{(Freq}_{input} - \text{Freq}_{IF})/n = \text{Freq}_{control} (900 \text{ MHz} - 0 \text{ MHz})/n = 900 \text{ MHz}/n$$

For  $n=0.5, 1, 2, 3$ , etc., the frequency of the control signal **2006** should be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc. The frequency of the down-converted PSK signal is substantially equal to one half the difference between the lower frequency  $F_1$  and the upper frequency  $F_2$ .

As another example, to down-convert a FSK signal to an amplitude shift keying (ASK) signal (a subset of AM), either the lower frequency  $F_1$  or the upper frequency  $F_2$  of the FSK signal is down-converted to zero IF. For example, to down-convert an FSK signal having  $F_1$  equal to 900 MHz and  $F_2$  equal to 901 MHz, to an ASK signal, the aliasing rate of the control signal **2006** should be substantially equal to:

$$\begin{aligned} (900 \text{ MHz} - 0 \text{ MHz})/n &= 900 \text{ MHz}/n, \text{ or} \\ (901 \text{ MHz} - 0 \text{ MHz})/n &= 901 \text{ MHz}/n. \end{aligned}$$

For the former case of 900 MHz/ $n$ , and for  $n=0.5, 1, 2, 3, 4$ , etc., the frequency of the control signal **2006** should be substantially equal to 1.8 GHz, 900 MHz, 450 MHz, 300 MHz, 225 MHz, etc. For the latter case of 901 MHz/ $n$ , and for  $n=0.5, 1, 2, 3, 4$ , etc., the frequency of the control signal **2006** should be substantially equal to 1.802 GHz, 901 MHz, 450.5 MHz, 300.333 MHz, 225.25 MHz, etc. The frequency of the down-converted AM signal is substantially equal to the difference between the lower frequency  $F_1$  and the upper frequency  $F_2$  (i.e., 1 MHz).

Exemplary time domain and frequency domain drawings, illustrating down-conversion of FM signals to non-FM signals, and exemplary methods and systems thereof, are disclosed in the co-pending U.S. patent application entitled “Method and System for Down-converting Electromagnetic Signals,” application Ser. No. 09/176,022, Attorney Docket Number 1744.0010000.

In an embodiment, the pulses of the control signal **2006** have negligible apertures that tend towards zero. This makes the UFT module **2002** a high input impedance device. This configuration is useful for situations where minimal disturbance of the input signal may be desired.

In another embodiment, the pulses of the control signal **2006** have non-negligible apertures that tend away from zero. This makes the UFT module **2002** a lower input impedance device. This allows the lower input impedance of the UFT module **2002** to be substantially matched with a source impedance of the input signal **2004**. This also improves the energy transfer from the input signal **2004** to the down-converted output signal **2012**, and hence the efficiency and signal to noise (s/n) ratio of UFT module **2002**.

Exemplary systems and methods for generating and optimizing the control signal **2006**, and for otherwise improving energy transfer and s/n ratio, are disclosed in the co-pending U.S. patent application entitled "Method and System for Down-converting Electromagnetic Signals," application Ser. No. 09/176,022, Attorney Docket Number 1744.0010000.

#### Frequency Up-conversion

The present invention is directed to systems and methods of frequency up-conversion, and applications of same.

An example frequency up-conversion system **300** is illustrated in FIG. 3. The frequency up-conversion system **300** is now described.

An input signal **302** (designated as "Control Signal" in FIG. 3) is accepted by a switch module **304**. For purposes of example only, assume that the input signal **302** is a FM input signal **606**, an example of which is shown in FIG. 6C. FM input signal **606** may have been generated by modulating information signal **602** onto oscillating signal **604** (FIGS. 6A and 6B). It should be understood that the invention is not limited to this embodiment. The information signal **602** can be analog, digital, or any combination thereof, and any modulation scheme can be used.

The output of switch module **304** is a harmonically rich signal **306**, shown for example in FIG. 6D as a harmonically rich signal **608**. The harmonically rich signal **608** has a continuous and periodic waveform.

FIG. 6E is an expanded view of two sections of harmonically rich signal **608**, section **610** and section **612**. The harmonically rich signal **608** may be a rectangular wave, such as a square wave or a pulse (although, the invention is not limited to this embodiment). For ease of discussion, the term "rectangular waveform" is used to refer to waveforms that are substantially rectangular. In a similar manner, the term "square wave" refers to those waveforms that are substantially square and it is not the intent of the present invention that a perfect square wave be generated or needed.

Harmonically rich signal **608** is comprised of a plurality of sinusoidal waves whose frequencies are integer multiples of the fundamental frequency of the waveform of the harmonically rich signal **608**. These sinusoidal waves are referred to as the harmonics of the underlying waveform, and the fundamental frequency is referred to as the first harmonic. FIG. 6F and FIG. 6G show separately the sinusoidal components making up the first, third, and fifth harmonics of section **610** and section **612**. (Note that in theory there may be an infinite number of harmonics; in this example, because harmonically rich signal **608** is shown as a square wave, there are only odd harmonics). Three harmonics are shown simultaneously (but not summed) in FIG. 6H.

The relative amplitudes of the harmonics are generally a function of the relative widths of the pulses of harmonically rich signal **306** and the period of the fundamental frequency, and can be determined by doing a Fourier analysis of harmonically rich signal **306**. According to an embodiment of the invention, the input signal **606** may be shaped to ensure that the amplitude of the desired harmonic is sufficient for its intended use (e.g., transmission).

A filter **308** filters out any undesired frequencies (harmonics), and outputs an electromagnetic (EM) signal at the desired harmonic frequency or frequencies as an output signal **310**, shown for example as a filtered output signal **614** in FIG. 6I.

FIG. 4 illustrates an example universal frequency up-conversion (UFU) module **401**. The UFU module **401** includes an example switch module **304**, which comprises a

bias signal **402**, a resistor or impedance **404**, a universal frequency translator (UFT) **450**, and a ground **408**. The UFT **450** includes a switch **406**. The input signal **302** (designated as "Control Signal" in FIG. 4) controls the switch **406** in the UFT **450**, and causes it to close and open. Harmonically rich signal **306** is generated at a node **405** located between the resistor or impedance **404** and the switch **406**.

Also in FIG. 4, it can be seen that an example filter **308** is comprised of a capacitor **410** and an inductor **412** shunted to a ground **414**. The filter is designed to filter out the undesired harmonics of harmonically rich signal **306**.

The invention is not limited to the UFU embodiment shown in FIG. 4.

For example, in an alternate embodiment shown in FIG. 5, an unshaped input signal **501** is routed to a pulse shaping module **502**. The pulse shaping module **502** modifies the unshaped input signal **501** to generate a (modified) input signal **302** (designated as the "Control Signal" in FIG. 5). The input signal **302** is routed to the switch module **304**, which operates in the manner described above. Also, the filter **308** of FIG. 5 operates in the manner described above.

The purpose of the pulse shaping module **502** is to define the pulse width of the input signal **302**. Recall that the input signal **302** controls the opening and closing of the switch **406** in switch module **304**. During such operation, the pulse width of the input signal **302** establishes the pulse width of the harmonically rich signal **306**. As stated above, the relative amplitudes of the harmonics of the harmonically rich signal **306** are a function of at least the pulse width of the harmonically rich signal **306**. As such, the pulse width of the input signal **302** contributes to setting the relative amplitudes of the harmonics of harmonically rich signal **306**.

Further details of up-conversion as described in this section are presented in pending U.S. application "Method and System for Frequency Up-Conversion," Ser. No. 09/176,154, filed Oct. 21, 1998, incorporated herein by reference in its entirety.

#### Enhanced Signal Reception

The present invention is directed to systems and methods of enhanced signal reception (ESR), and applications of same.

Referring to FIG. 21, transmitter **2104** accepts a modulating baseband signal **2102** and generates (transmitted) redundant spectrums **2106a-n**, which are sent over communications medium **2108**. Receiver **2112** recovers a demodulated baseband signal **2114** from (received) redundant spectrums **2110a-n**. Demodulated baseband signal **2114** is representative of the modulating baseband signal **2102**, where the level of similarity between the modulating baseband signal **2114** and the modulating baseband signal **2102** is application dependent.

Modulating baseband signal **2102** is preferably any information signal desired for transmission and/or reception. An example modulating baseband signal **2202** is illustrated in FIG. 22A, and has an associated modulating baseband spectrum **2204** and image spectrum **2203** that are illustrated in FIG. 22B. Modulating baseband signal **2202** is illustrated as an analog signal in FIG. 22a, but could also be a digital signal, or combination thereof. Modulating baseband signal **2202** could be a voltage (or current) characterization of any number of real world occurrences, including for example and without limitation, the voltage (or current) representation for a voice signal.

Each transmitted redundant spectrum **2106a-n** contains the necessary information to substantially reconstruct the modulating baseband signal **2102**. In other words, each

redundant spectrum **2106a-n** contains the necessary amplitude, phase, and frequency information to reconstruct the modulating baseband signal **2102**.

FIG. **22C** illustrates example transmitted redundant spectrums **2206b-d**. Transmitted redundant spectrums **2206b-d** are illustrated to contain three redundant spectrums for illustration purposes only. Any number of redundant spectrums could be generated and transmitted as will be explained in following discussions.

Transmitted redundant spectrums **2206b-d** are centered at  $f_1$ , with a frequency spacing  $f_2$  between adjacent spectrums. Frequencies  $f_1$  and  $f_2$  are dynamically adjustable in real-time as will be shown below. FIG. **22D** illustrates an alternate embodiment, where redundant spectrums **2208c,d** are centered on unmodulated oscillating signal **2209** at  $f_1$  (Hz). Oscillating signal **2209** may be suppressed if desired using, for example, phasing techniques or filtering techniques. Transmitted redundant spectrums are preferably above baseband frequencies as is represented by break **2205** in the frequency axis of FIGS. **22C** and **22D**.

Received redundant spectrums **2210a-n** are substantially similar to transmitted redundant spectrums **2106a-n**, except for the changes introduced by the communications medium **2108**. Such changes can include but are not limited to signal attenuation, and signal interference. FIG. **22E** illustrates example received redundant spectrums **2210b-d**. Received redundant spectrums **2210b-d** are substantially similar to transmitted redundant spectrums **2206b-d**, except that redundant spectrum **2210c** includes an undesired jamming signal spectrum **2211** in order to illustrate some advantages of the present invention. Jamming signal spectrum **2211** is a frequency spectrum associated with a jamming signal. For purposes of this invention, a "jamming signal" refers to any unwanted signal, regardless of origin, that may interfere with the proper reception and reconstruction of an intended signal. Furthermore, the jamming signal is not limited to tones as depicted by spectrum **2211**, and can have any spectral shape, as will be understood by those skilled in the art(s).

As stated above, demodulated baseband signal **2114** is extracted from one or more of received redundant spectrums **2210b-d**. FIG. **22F** illustrates example demodulated baseband signal **2212** that is, in this example, substantially similar to modulating baseband signal **2202** (FIG. **22A**); where in practice, the degree of similarity is application dependent.

An advantage of the present invention should now be apparent. The recovery of modulating baseband signal **2202** can be accomplished by receiver **2112** in spite of the fact that high strength jamming signal(s) (e.g. jamming signal spectrum **2211**) exist on the communications medium. The intended baseband signal can be recovered because multiple redundant spectrums are transmitted, where each redundant spectrum carries the necessary information to reconstruct the baseband signal. At the destination, the redundant spectrums are isolated from each other so that the baseband signal can be recovered even if one or more of the redundant spectrums are corrupted by a jamming signal.

Transmitter **2104** will now be explored in greater detail. FIG. **23A** illustrates transmitter **2301**, which is one embodiment of transmitter **2104** that generates redundant spectrums configured similar to redundant spectrums **2206b-d**. Transmitter **2301** includes generator **2303**, optional spectrum processing module **2304**, and optional medium interface module **2320**. Generator **2303** includes: first oscillator **2302**, second oscillator **2309**, first stage modulator **2306**, and second stage modulator **2310**.

Transmitter **2301** operates as follows. First oscillator **2302** and second oscillator **2309** generate a first oscillating signal **2305** and second oscillating signal **2312**, respectively. First stage modulator **2306** modulates first oscillating signal **2305** with modulating baseband signal **2202**, resulting in modulated signal **2308**. First stage modulator **2306** may implement any type of modulation including but not limited to: amplitude modulation, frequency modulation, phase modulation, combinations thereof, or any other type of modulation. Second stage modulator **2310** modulates modulated signal **2308** with second oscillating signal **2312**, resulting in multiple redundant spectrums **2206a-n** shown in FIG. **23B**. Second stage modulator **2310** is preferably a phase modulator, or a frequency modulator, although other types of modulation may be implemented including but not limited to amplitude modulation. Each redundant spectrum **2206a-n** contains the necessary amplitude, phase, and frequency information to substantially reconstruct the modulating baseband signal **2202**.

Redundant spectrums **2206a-n** are substantially centered around  $f_1$  which is the characteristic frequency of first oscillating signal **2305**. Also, each redundant spectrum **2206a-n** (except for **2206c**) is offset from  $f_1$  by approximately a multiple of  $f_2$  (Hz), where  $f_2$  is the frequency of the second oscillating signal **2312**. Thus, each redundant spectrum **2206a-n** is offset from an adjacent redundant spectrum by  $f_2$  (Hz). This allows the spacing between adjacent redundant spectrums to be adjusted (or tuned) by changing  $f_2$  that is associated with second oscillator **2309**. Adjusting the spacing between adjacent redundant spectrums allows for dynamic real-time tuning of the bandwidth occupied by redundant spectrums **2206a-n**.

In one embodiment, the number of redundant spectrums **2206a-n** generated by transmitter **2301** is arbitrary and may be unlimited as indicated by the "a-n" designation for redundant spectrums **2206a-n**. However, a typical communications medium will have a physical and/or administrative limitations (i.e. FCC regulations) that restrict the number of redundant spectrums that can be practically transmitted over the communications medium. Also, there may be other reasons to limit the number of redundant spectrums transmitted. Therefore, preferably, the transmitter **2301** will include an optional spectrum processing module **2304** to process the redundant spectrums **2206a-n** prior to transmission over communications medium **2108**.

In one embodiment, spectrum processing module **2304** includes a filter with a passband **2207** (FIG. **23C**) to select redundant spectrums **2206b-d** for transmission. This will substantially limit the frequency bandwidth occupied by the redundant spectrums to the passband **2207**. In one embodiment, spectrum processing module **2304** also up converts redundant spectrums and/or amplifies redundant spectrums prior to transmission over the communications medium **2108**. Finally, medium interface module **2320** transmits redundant spectrums over the communications medium **2108**. In one embodiment, communications medium **2108** is an over-the-air link and medium interface module **2320** is an antenna. Other embodiments for communications medium **2108** and medium interface module **2320** will be understood based on the teachings contained herein.

FIG. **23D** illustrates transmitter **2321**, which is one embodiment of transmitter **2104** that generates redundant spectrums configured similar to redundant spectrums **2208c-d** and unmodulated spectrum **2209**. Transmitter **2321** includes generator **2311**, spectrum processing module **2304**, and (optional) medium interface module **2320**. Generator **2311** includes: first oscillator **2302**, second oscillator **2309**, first stage modulator **2306**, and second stage modulator **2310**.

As shown in FIG. 23D, many of the components in transmitter 2321 are similar to those in transmitter 2301. However, in this embodiment, modulating baseband signal 2202 modulates second oscillating signal 2312. Transmitter 2321 operates as follows. First stage modulator 2306 modulates second oscillating signal 2312 with modulating baseband signal 2202, resulting in modulated signal 2322. As described earlier, first stage modulator 2306 can effect any type of modulation including but not limited to: amplitude modulation frequency modulation, combinations thereof, or any other type of modulation. Second stage modulator 2310 modulates first oscillating signal 2304 with modulated signal 2322, resulting in redundant spectrums 2208a-n, as shown in FIG. 23E. Second stage modulator 2310 is preferably a phase or frequency modulator, although other modulators could used including but not limited to an amplitude modulator.

Redundant spectrums 2208a-n are centered on unmodulated spectrum 2209 (at  $f_1$  Hz), and adjacent spectrums are separated by  $f_2$  Hz. The number of redundant spectrums 2208a-n generated by generator 2311 is arbitrary and unlimited, similar to spectrums 2206a-n discussed above. Therefore, optional spectrum processing module 2304 may also include a filter with passband 2325 to select, for example, spectrums 2208c,d for transmission over communications medium 2108. In addition, optional spectrum processing module 2304 may also include a filter (such as a bandstop filter) to attenuate unmodulated spectrum 2209. Alternatively, unmodulated spectrum 2209 may be attenuated by using phasing techniques during redundant spectrum generation. Finally, (optional) medium interface module 2320 transmits redundant spectrums 2208c,d over communications medium 2108.

Receiver 2112 will now be explored in greater detail to illustrate recovery of a demodulated baseband signal from received redundant spectrums. FIG. 24A illustrates receiver 2430, which is one embodiment of receiver 2112. Receiver 2430 includes optional medium interface module 2402, down-converter 2404, spectrum isolation module 2408, and data extraction module 2414. Spectrum isolation module 2408 includes filters 2410a-c. Data extraction module 2414 includes demodulators 2416a-c, error check modules 2420a-c, and arbitration module 2424. Receiver 2430 will be discussed in relation to the signal diagrams in FIGS. 24B-24J.

In one embodiment, optional medium interface module 2402 receives redundant spectrums 2210b-d (FIG. 22E, and FIG. 24B). Each redundant spectrum 2210b-d includes the necessary amplitude, phase, and frequency information to substantially reconstruct the modulating baseband signal used to generate the redundant spectrums. However, in the present example, spectrum 2210c also contains jamming signal 2211, which may interfere with the recovery of a baseband signal from spectrum 2210c. Down-converter 2404 down-converts received redundant spectrums 2210b-d to lower intermediate frequencies, resulting in redundant spectrums 2406a-c (FIG. 24C). Jamming signal 2211 is also down-converted to jamming signal 2407, as it is contained within redundant spectrum 2406b. Spectrum isolation module 2408 includes filters 2410a-c that isolate redundant spectrums 2406a-c from each other (FIGS. 24D-24F, respectively). Demodulators 2416a-c independently demodulate spectrums 2406a-c, resulting in demodulated baseband signals 2418a-c, respectively (FIGS. 24G-24I). Error check modules 2420a-c analyze demodulated baseband signal 2418a-c to detect any errors. In one embodiment, each error check module 2420a-c sets an error flag 2422a-c

whenever an error is detected in a demodulated baseband signal. Arbitration module 2424 accepts the demodulated baseband signals and associated error flags, and selects a substantially error-free demodulated baseband signal (FIG. 24J). In one embodiment, the substantially error-free demodulated baseband signal will be substantially similar to the modulating baseband signal used to generate the received redundant spectrums, where the degree of similarity is application dependent.

Referring to FIGS. 24G-I, arbitration module 2424 will select either demodulated baseband signal 2418a or 2418c, because error check module 2420b will set the error flag 2422b that is associated with demodulated baseband signal 2418b.

The error detection schemes implemented by the error detection modules include but are not limited to: cyclic redundancy check (CRC) and parity check for digital signals, and various error detections schemes for analog signal.

Further details of enhanced signal reception as described in this section are presented in pending U.S. application "Method and System for Ensuring Reception of a Communications Signal," Ser. No. 09/176,415, filed Oct. 21, 1998, incorporated herein by reference in its entirety.

#### Unified Down-conversion and Filtering

The present invention is directed to systems and methods of unified down-conversion and filtering (UDF), and applications of same.

In particular, the present invention includes a unified down-converting and filtering (UDF) module that performs frequency selectivity and frequency translation in a unified (i.e., integrated) manner. By operating in this manner, the invention achieves high frequency selectivity prior to frequency translation (the invention is not limited to this embodiment). The invention achieves high frequency selectivity at substantially any frequency, including but not limited to RF (radio frequency) and greater frequencies. It should be understood that the invention is not limited to this example of RF and greater frequencies. The invention is intended, adapted, and capable of working with lower than radio frequencies.

FIG. 17 is a conceptual block diagram of a UDF module 1702 according to an embodiment of the present invention. The UDF module 1702 performs at least frequency translation and frequency selectivity.

The effect achieved by the UDF module 1702 is to perform the frequency selectivity operation prior to the performance of the frequency translation operation. Thus, the UDF module 1702 effectively performs input filtering.

According to embodiments of the present invention, such input filtering involves a relatively narrow bandwidth. For example, such input filtering may represent channel select filtering, where the filter bandwidth may be, for example, 50 KHz to 150 KHz. It should be understood, however, that the invention is not limited to these frequencies. The invention is intended, adapted, and capable of achieving filter bandwidths of less than and greater than these values.

In embodiments of the invention, input signals 1704 received by the UDF module 1702 are at radio frequencies. The UDF module 1702 effectively operates to input filter these RF input signals 1704. Specifically, in these embodiments, the UDF module 1702 effectively performs input, channel select filtering of the RF input signal 1704. Accordingly, the invention achieves high selectivity at high frequencies.

The UDF module 1702 effectively performs various types of filtering, including but not limited to bandpass filtering,

low pass filtering, highpass filtering, notch filtering, all pass filtering, band stop filtering, etc., and combinations thereof.

Conceptually, the UDF module 1702 includes a frequency translator 1708. The frequency translator 1708 conceptually represents that portion of the UDF module 1702 that performs frequency translation (down conversion).

The UDF module 1702 also conceptually includes an apparent input filter 1706 (also sometimes called an input filtering emulator). Conceptually, the apparent input filter 1706 represents that portion of the UDF module 1702 that performs input filtering.

In practice, the input filtering operation performed by the UDF module 1702 is integrated with the frequency translation operation. The input filtering operation can be viewed as being performed concurrently with the frequency translation operation. This is a reason why the input filter 1706 is herein referred to as an "apparent" input filter 1706.

The UDF module 1702 of the present invention includes a number of advantages. For example, high selectivity at high frequencies is realizable using the UDF module 1702. This feature of the invention is evident by the high Q factors that are attainable. For example, and without limitation, the UDF module 1702 can be designed with a filter center frequency  $f_C$  on the order of 900 MHz, and a filter bandwidth on the order of 50 KHz. This represents a Q of 18,000 (Q is equal to the center frequency divided by the bandwidth).

It should be understood that the invention is not limited to filters with high Q factors. The filters contemplated by the present invention may have lesser or greater Qs, depending on the application, design, and/or implementation. Also, the scope of the invention includes filters where Q factor as discussed herein is not applicable.

The invention exhibits additional advantages. For example, the filtering center frequency  $f_C$  of the UDF module 1702 can be electrically adjusted, either statically or dynamically.

Also, the UDF module 1702 can be designed to amplify input signals.

Further, the UDF module 1702 can be implemented without large resistors, capacitors, or inductors. Also, the UDF module 1702 does not require that tight tolerances be maintained on the values of its individual components, i.e., its resistors, capacitors, inductors, etc. As a result, the architecture of the UDF module 1702 is friendly to integrated circuit design techniques and processes.

The features and advantages exhibited by the UDF module 1702 are achieved at least in part by adopting a new technological paradigm with respect to frequency selectivity and translation. Specifically, according to the present invention, the UDF module 1702 performs the frequency selectivity operation and the frequency translation operation as a single, unified (integrated) operation. According to the invention, operations relating to frequency translation also contribute to the performance of frequency selectivity, and vice versa.

According to embodiments of the present invention, the UDF module generates an output signal from an input signal using samples/instances of the input signal and samples/instances of the output signal.

More particularly, first, the input signal is under-sampled. This input sample includes information (such as amplitude, phase, etc.) representative of the input signal existing at the time the sample was taken.

As described further below, the effect of repetitively performing this step is to translate the frequency (that is, down-convert) of the input signal to a desired lower frequency, such as an intermediate frequency (IF) or base-band.

Next, the input sample is held (that is, delayed).

Then, one or more delayed input samples (some of which may have been scaled) are combined with one or more delayed instances of the output signal (some of which may have been scaled) to generate a current instance of the output signal.

Thus, according to preferred embodiment of the invention, the output signal is generated from prior samples/instances of the input signal and/or the output signal. (It is noted that, in some embodiments of the invention, current samples/instances of the input signal and/or the output signal may be used to generate current instances of the output signal.) By operating in this manner, the UDF module preferably performs input filtering and frequency down-conversion in a unified manner.

FIG. 19 illustrates an example implementation of the unified down-converting and filtering (UDF) module 1922. The UDF module 1922 performs the frequency translation operation and the frequency selectivity operation in an integrated, unified manner as described above, and as further described below.

In the example of FIG. 19, the frequency selectivity operation performed by the UDF module 1922 comprises a band-pass filtering operation according to EQ. 1, below, which is an example representation of a band-pass filtering transfer function.

$$VO = \alpha_1 z^{-1} VI - \beta_1 z^{-1} VO - \beta_0 z^{-2} VO \quad \text{EQ. 1}$$

It should be noted, however, that the invention is not limited to band-pass filtering. Instead, the invention effectively performs various types of filtering, including but not limited to bandpass filtering, low pass filtering, high pass filtering, notch filtering, all pass filtering, band stop filtering, etc., and combinations thereof. As will be appreciated, there are many representations of any given filter type. The invention is applicable to these filter representations. Thus, EQ. 1 is referred to herein for illustrative purposes only, and is not limiting.

The UDF module 1922 includes a down-convert and delay module 1924, first and second delay modules 1928 and 1930, first and second scaling modules 1932 and 1934, an output sample and hold module 1936, and an (optional) output smoothing module 1938. Other embodiments of the UDF module will have these components in different configurations, and/or a subset of these components, and/or additional components. For example, and without limitation, in the configuration shown in FIG. 19, the output smoothing module 1938 is optional.

As further described below, in the example of FIG. 19, the down-convert and delay module 1924 and the first and second delay modules 1928 and 1930 include switches that are controlled by a clock having two phases,  $\phi_1$  and  $\phi_2$ .  $\phi_1$  and  $\phi_2$  preferably have the same frequency, and are non-overlapping (alternatively, a plurality such as two clock signals having these characteristics could be used). As used herein, the term "non-overlapping" is defined as two or more signals where only one of the signals is active at any given time. In some embodiments, signals are "active" when they are high. In other embodiments, signals are active when they are low.

Preferably, each of these switches closes on a rising edge of  $\phi_1$  or  $\phi_2$ , and opens on the next corresponding falling edge of  $\phi_1$  or  $\phi_2$ . However, the invention is not limited to this example. As will be apparent to persons skilled in the relevant art(s), other clock conventions can be used to control the switches.

In the example of FIG. 19, it is assumed that  $\alpha_1$  is equal to one. Thus, the output of the down-convert and delay

module 1924 is not scaled. As evident from the embodiments described above, however, the invention is not limited to this example.

The example UDF module 1922 has a filter center frequency of 900.2 MHz and a filter bandwidth of 570 KHz. The pass band of the UDF module 1922 is on the order of 899.915 MHz to 900.485 MHz. The Q factor of the UDF module 1922 is approximately 1879 (i.e., 900.2 MHz divided by 570 KHz).

The operation of the UDF module 1922 shall now be described with reference to a Table 1802 (FIG. 18) that indicates example values at nodes in the UDF module 1922 at a number of consecutive time increments. It is assumed in Table 1802 that the UDF module 1922 begins operating at time t-1. As indicated below, the UDF module 1922 reaches steady state a few time units after operation begins. The number of time units necessary for a given UDF module to reach steady state depends on the configuration of the UDF module, and will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

At the rising edge of  $\phi_1$  at time t-1, a switch 1950 in the down-convert and delay module 1924 closes. This allows a capacitor 1952 to charge to the current value of an input signal,  $VI_{t-1}$ , such that node 1902 is at  $VI_{t-1}$ . This is indicated by cell 1804 in FIG. 18. In effect, the combination of the switch 1950 and the capacitor 1952 in the down-convert and delay module 1924 operates to translate the frequency of the input signal VI to a desired lower frequency, such as IF or baseband. Thus, the value stored in the capacitor 1952 represents an instance of a down-converted image of the input signal VI.

The manner in which the down-convert and delay module 1924 performs frequency down-conversion is further described elsewhere in this application, and is additionally described in pending U.S. application "Method and System for Down-Converting Electromagnetic Signals," Ser. No. 09/176,022, filed Oct. 21, 1998, which is herein incorporated by reference in its entirety.

Also at the rising edge of  $\phi_1$  at time t-1, a switch 1958 in the first delay module 1928 closes, allowing a capacitor 1960 to charge to  $VO_{t-1}$ , such that node 1906 is at  $VO_{t-1}$ . This is indicated by cell 1806 in Table 1802. (In practice,  $VO_{t-1}$  is undefined at this point. However, for ease of understanding,  $VO_{t-1}$  shall continue to be used for purposes of explanation.)

Also at the rising edge of  $\phi_1$  at time t-1, a switch 1966 in the second delay module 1930 closes, allowing a capacitor 1968 to charge to a value stored in a capacitor 1964. At this time, however, the value in capacitor 1964 is undefined, so the value in capacitor 1968 is undefined. This is indicated by cell 1807 in table 1802.

At the rising edge of  $\phi_2$  at time t-1, a switch 1954 in the down-convert and delay module 1924 closes, allowing a capacitor 1956 to charge to the level of the capacitor 1952. Accordingly, the capacitor 1956 charges to  $VI_{t-1}$ , such that node 1904 is at  $VI_{t-1}$ . This is indicated by cell 1810 in Table 1802.

The UDF module 1922 may optionally include a unity gain module 1990A between capacitors 1952 and 1956. The unity gain module 1990A operates as a current source to enable capacitor 1956 to charge without draining the charge from capacitor 1952. For a similar reason, the UDF module 1922 may include other unity gain modules 1990B-1990G. It should be understood that, for many embodiments and applications of the invention, these unity gain modules 1990A-1990G are optional. The structure and operation of the unity gain modules 1990 will be apparent to persons skilled in the relevant art(s).

Also at the rising edge of  $\phi_2$  at time t-1, a switch 1962 in the first delay module 1928 closes, allowing a capacitor 1964 to charge to the level of the capacitor 1960. Accordingly, the capacitor 1964 charges to  $VO_{t-1}$ , such that node 1908 is at  $VO_{t-1}$ . This is indicated by cell 1814 in Table 1802.

Also at the rising edge of  $\phi_2$  at time t-1, a switch 1970 in the second delay module 1930 closes, allowing a capacitor 1972 to charge to a value stored in a capacitor 1968. At this time, however, the value in capacitor 1968 is undefined, so the value in capacitor 1972 is undefined. This is indicated by cell 1815 in table 1802.

At time t, at the rising edge of  $\phi_1$ , the switch 1950 in the down-convert and delay module 1924 closes. This allows the capacitor 1952 to charge to  $VI_t$ , such that node 1902 is at  $VI_t$ . This is indicated in cell 1816 of Table 1802.

Also at the rising edge of  $\phi_1$  at time t, the switch 1958 in the first delay module 1928 closes, thereby allowing the capacitor 1960 to charge to  $VO_t$ . Accordingly, node 1906 is at  $VO_t$ . This is indicated in cell 1820 in Table 1802.

Further at the rising edge of  $\phi_1$  at time t, the switch 1966 in the second delay module 1930 closes, allowing a capacitor 1968 to charge to the level of the capacitor 1964. Therefore, the capacitor 1968 charges to  $VO_{t-1}$ , such that node 1910 is at  $VO_{t-1}$ . This is indicated by cell 1824 in Table 1802.

At the rising edge of  $\phi_2$  at time t, the switch 1954 in the down-convert and delay module 1924 closes, allowing the capacitor 1956 to charge to the level of the capacitor 1952. Accordingly, the capacitor 1956 charges to  $VI_t$ , such that node 1904 is at  $VI_t$ . This is indicated by cell 1828 in Table 1802.

Also at the rising edge of  $\phi_2$  at time t, the switch 1962 in the first delay module 1928 closes, allowing the capacitor 1964 to charge to the level in the capacitor 1960. Therefore, the capacitor 1964 charges to  $VO_t$ , such that node 1908 is at  $VO_t$ . This is indicated by cell 1832 in Table 1802.

Further at the rising edge of  $\phi_2$  at time t, the switch 1970 in the second delay module 1930 closes, allowing the capacitor 1972 in the second delay module 1930 to charge to the level of the capacitor 1968 in the second delay module 1930. Therefore, the capacitor 1972 charges to  $VO_{t-1}$ , such that node 1912 is at  $VO_{t-1}$ . This is indicated in cell 1836 of FIG. 18.

At time t+1, at the rising edge of  $\phi_1$ , the switch 1950 in the down-convert and delay module 1924 closes, allowing the capacitor 1952 to charge to  $VI_{t+1}$ . Therefore, node 1902 is at  $VI_{t+1}$ , as indicated by cell 1838 of Table 1802.

Also at the rising edge of  $\phi_1$  at time t+1, the switch 1958 in the first delay module 1928 closes, allowing the capacitor 1960 to charge to  $VO_{t+1}$ . Accordingly, node 1906 is at  $VO_{t+1}$ , as indicated by cell 1842 in Table 1802.

Further at the rising edge of  $\phi_1$ , at time t+1, the switch 1966 in the second delay module 1930 closes, allowing the capacitor 1968 to charge to the level of the capacitor 1964. Accordingly, the capacitor 1968 charges to  $VO_t$ , as indicated by cell 1846 of Table 1802.

In the example of FIG. 19, the first scaling module 1932 scales the value at node 1908 (i.e., the output of the first delay module 1928) by a scaling factor of -0.1. Accordingly, the value present at node 1914 at time t+1 is  $-0.1 * VO_t$ . Similarly, the second scaling module 1934 scales the value present at node 1912 (i.e., the output of the second scaling module 1930) by a scaling factor of -0.8. Accordingly, the value present at node 1916 is  $-0.8 * VO_{t-1}$  at time t+1.

At time t+1, the values at the inputs of the summer 1926 are:  $VI_t$  at node 1904,  $-0.1 * VO_t$  at node 1914, and  $-0.8 *$

$VO_{t-1}$  at node **1916** (in the example of FIG. **19**, the values at nodes **1914** and **1916** are summed by a second summer **1925**, and this sum is presented to the summer **1926**). Accordingly, at time  $t+1$ , the summer generates a signal equal to  $VI_t - 0.1 * VO_t - 0.8 * VO_{t-1}$ .

At the rising edge of  $\phi_1$  at time  $t+1$ , a switch **1991** in the output sample and hold module **1936** closes, thereby allowing a capacitor **1992** to charge to  $VO_{t+1}$ . Accordingly, the capacitor **1992** charges to  $VO_{t+1}$ , which is equal to the sum generated by the adder **1926**. As just noted, this value is equal to:  $VI_t - 0.1 * VO_t - 0.8 * VO_{t-1}$ . This is indicated in cell **1850** of Table **1802**. This value is presented to the optional output smoothing module **1938**, which smooths the signal to thereby generate the instance of the output signal  $VO_{t+1}$ . It is apparent from inspection that this value of  $VO_{t+1}$  is consistent with the band pass filter transfer function of EQ. 1.

Further details of unified down-conversion and filtering as described in this section are presented in pending U.S. application "Integrated Frequency Translation And Selectivity," Ser. No. 09/175,966, filed Oct. 21, 1998, incorporated herein by reference in its entirety.

#### Example Application Embodiments of the Invention

As noted above, the UFT module of the present invention is a very powerful and flexible device. Its flexibility is illustrated, in part, by the wide range of applications in which it can be used. Its power is illustrated, in part, by the usefulness and performance of such applications.

Example applications of the UFT module were described above. In particular, frequency down-conversion, frequency up-conversion, enhanced signal reception, and unified down-conversion and filtering applications of the UFT module were summarized above, and are further described below. These applications of the UFT module are discussed herein for illustrative purposes. The invention is not limited to these example applications. Additional applications of the UFT module will be apparent to persons skilled in the relevant art(s), based on the teachings contained herein.

For example, the present invention can be used in applications that involve frequency down-conversion. This is shown in FIG. **1C**, for example, where an example UFT module **115** is used in a down-conversion module **114**. In this capacity, the UFT module **115** frequency down-converts an input signal to an output signal. This is also shown in FIG. **7**, for example, where an example UFT module **706** is part of a down-conversion module **704**, which is part of a receiver **702**.

The present invention can be used in applications that involve frequency up-conversion. This is shown in FIG. **1D**, for example, where an example UFT module **117** is used in a frequency up-conversion module **116**. In this capacity, the UFT module **117** frequency up-converts an input signal to an output signal. This is also shown in FIG. **8**, for example, where an example UFT module **806** is part of up-conversion module **804**, which is part of a transmitter **802**.

The present invention can be used in environments having one or more transmitters **902** and one or more receivers **906**, as illustrated in FIG. **9**. In such environments, one or more of the transmitters **902** may be implemented using a UFT module, as shown for example in FIG. **8**. Also, one or more of the receivers **906** may be implemented using a UFT module, as shown for example in FIG. **7**.

The invention can be used to implement a transceiver. An example transceiver **1002** is illustrated in FIG. **10**. The transceiver **1002** includes a transmitter **1004** and a receiver **1008**. Either the transmitter **1004** or the receiver **1008** can be implemented using a UFT module. Alternatively, the trans-

mitter **1004** can be implemented using a UFT module **1006**, and the receiver **1008** can be implemented using a UFT module **1010**. This embodiment is shown in FIG. **10**.

Another transceiver embodiment according to the invention is shown in FIG. **11**. In this transceiver **1102**, the transmitter **1104** and the receiver **1108** are implemented using a single UFT module **1106**. In other words, the transmitter **1104** and the receiver **1108** share a UFT module **1106**.

As described elsewhere in this application, the invention is directed to methods and systems for enhanced signal reception (ESR). Various ESR embodiments include an ESR module (transmit) in a transmitter **1202**, and an ESR module (receive) in a receiver **1210**. An example ESR embodiment configured in this manner is illustrated in FIG. **12**.

The ESR module (transmit) **1204** includes a frequency up-conversion module **1206**. Some embodiments of this frequency up-conversion module **1206** may be implemented using a UFT module, such as that shown in FIG. **1D**.

The ESR module (receive) **1212** includes a frequency down-conversion module **1214**. Some embodiments of this frequency down-conversion module **1214** may be implemented using a UFT module, such as that shown in FIG. **1C**.

As described elsewhere in this application, the invention is directed to methods and systems for unified down-conversion and filtering (UDF). An example unified down-conversion and filtering module **1302** is illustrated in FIG. **13**. The unified down-conversion and filtering module **1302** includes a frequency down-conversion module **1304** and a filtering module **1306**. According to the invention, the frequency down-conversion module **1304** and the filtering module **1306** are implemented using a UFT module **1308**, as indicated in FIG. **13**.

Unified down-conversion and filtering according to the invention is useful in applications involving filtering and/or frequency down-conversion. This is depicted, for example, in FIGS. **15A–15F**. FIGS. **15A–15C** indicate that unified down-conversion and filtering according to the invention is useful in applications where filtering precedes, follows, or both precedes and follows frequency down-conversion. FIG. **15D** indicates that a unified down-conversion and filtering module **1524** according to the invention can be utilized as a filter **1522** (i.e., where the extent of frequency down-conversion by the down-converter in the unified down-conversion and filtering module **1524** is minimized). FIG. **15E** indicates that a unified down-conversion and filtering module **1528** according to the invention can be utilized as a down-converter **1526** (i.e., where the filter in the unified down-conversion and filtering module **1528** passes substantially all frequencies). FIG. **15F** illustrates that the unified down-conversion and filtering module **1532** can be used as an amplifier. It is noted that one or more UDF modules can be used in applications that involve at least one or more of filtering, frequency translation, and amplification.

For example, receivers, which typically perform filtering, down-conversion, and filtering operations, can be implemented using one or more unified down-conversion and filtering modules. This is illustrated, for example, in FIG. **14**.

The methods and systems of unified down-conversion and filtering of the invention have many other applications. For example, as discussed herein, the enhanced signal reception (ESR) module (receive) operates to down-convert a signal containing a plurality of spectrums. The ESR module (receive) also operates to isolate the spectrums in the down-converted signal, where such isolation is implemented via filtering in some embodiments. According to embodiments of the invention, the ESR module (receive) is implemented

using one or more unified down-conversion and filtering (UDF) modules. This is illustrated, for example, in FIG. 16. In the example of FIG. 16, one or more of the UDF modules 1610, 1612, 1614 operates to down-convert a received signal. The UDF modules 1610, 1612, 1614 also operate to

filter the down-converted signal so as to isolate the spectrum (s) contained therein. As noted above, the UDF modules 1610, 1612, 1614 are implemented using the universal frequency translation (UFT) modules of the invention.

The invention is not limited to the applications of the UFT

module described above. For example, and without limitation, subsets of the applications (methods and/or structures) described herein (and others that would be apparent to persons skilled in the relevant art(s) based on the herein teachings) can be associated to form useful combinations.

For example, transmitters and receivers are two applications of the UFT module. FIG. 10 illustrates a transceiver 1002 that is formed by combining these two applications of the UFT module, i.e., by combining a transmitter 1004 with a receiver 1008.

Also, ESR (enhanced signal reception) and unified down-conversion and filtering are two other applications of the UFT module. FIG. 16 illustrates an example where ESR and unified down-conversion and filtering are combined to form a modified enhanced signal reception system.

The invention is not limited to the example applications of the UFT module discussed herein. Also, the invention is not limited to the example combinations of applications of the UFT module discussed herein. These examples were provided for illustrative purposes only, and are not limiting. Other applications and combinations of such applications will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. Such applications and combinations include, for example and without limitation, applications/combinations comprising and/or involving one or more of: (1) frequency translation; (2) frequency down-conversion; (3) frequency up-conversion; (4) receiving; (5) transmitting; (6) filtering; and/or (7) signal transmission and reception in environments containing potentially jamming signals.

Additional example applications are described below.

#### Telephones

The present invention is directed to telephones that employ the UFT module for performing down-conversion and/or up conversion operations. According to embodiments of the invention, telephones include a receiver that uses a UFT module for frequency down-conversion (see, for example, FIG. 7), and/or a transmitter that uses a UFT module for frequency up-conversion (see, for example, FIG. 8). Alternatively, telephone embodiments of the invention employ a transceiver that utilizes one or more UFT modules for performing frequency down-conversion and/or up-conversion operations, as shown, for example, in FIGS. 10 and 11.

Any type of telephone falls within the scope and spirit of the present invention, including but not limited to cordless phones (wherein UFT modules can be used in both the base unit and the handset to communicate therebetween, and in the base unit to communicate with the telephone company via wired or wireless service), cellular phones, satellite phones, etc.

FIG. 25 illustrates an example environment 2502 illustrating cellular phones and satellite phones according to embodiments of the invention. Cellular phones 2504, 2508, 2512 and 2516 each include a transceiver 2506, 2510, 2514, and 2518, respectively. Transceivers 2506, 2510, 2514, and

2518 enable their respective cellular phones to communicate via a wireless communication medium with base stations 2520, 2524. According to the invention, the transceivers 2506, 2510, 2514, and 2518 are implemented using one or more UFT modules. FIGS. 10 and 11 illustrate example transceivers 1002 and 1102 operable for use with the cellular phones of the present invention. Alternatively, one or more of cellular telephones 2504, 2508, 2512, and 2516 may employ transmitter modules and receiver modules. Either or both of such transmitter modules and receiver modules may be implemented using UFT modules as shown in FIGS. 7 and 8, for example.

FIG. 25 also illustrates a satellite telephone 2590 that communicates via satellites, such as satellite 2526. The satellite telephone 2590 includes a transceiver 2592, which is preferably implemented using one or more UFT modules, such as shown in FIGS. 10 and 11, for example. Alternatively, the satellite phone 2590 may include a receiver module and a transmitter module, wherein either or both of the receiver module and the transmitter module is implemented using a UFT module, as shown, for example, in FIGS. 7 and 8.

FIG. 25 also illustrates a cordless phone 2590 having a handset 2592 and a base station 2596. The handset 2592 and the base station 2596 include transceivers 2594, 2598 for communicating with each other preferably over a wireless link. Transceivers 2594, 2598 are preferably implemented using one or more UFT modules, such as shown in FIGS. 10 and 11, for example. Alternatively, transceivers 2594, 2598 each may be replaced by a receiver module and a transmitter module, wherein either or both of the receiver module and the transmitter module is implemented using a UFT module, as shown, for example, in FIGS. 7 and 8. In embodiments, the base station 2596 of the cordless phone 2590 may communicate with the base station 2520 via transceivers 2598, 2521, or using other communication modules.

#### Base Stations

The invention is directed to communication base stations that generally represent interfaces between telephones and telephone networks. Example base stations 2520, 2524 according to the invention are illustrated in FIG. 25. The invention is directed to other types of base stations, such as but not limited to base stations in cordless phones (see, for example, base station 2596 in cordless phone 2590 in FIG. 25). The base stations 2520, 2524, 2596 each include a transceiver 2521, 2525, 2598. According to embodiments of the invention, the transceivers 2521, 2525, 2598 are each implemented using one or more UFT modules (see, for example, FIGS. 10 and 11). Alternatively, the base stations 2520, 2524, 2596 can be implemented using receiver modules and transmitter modules, wherein either or both of the receiver and transmitter modules are implemented using UFT modules (see, for example, FIGS. 7 and 8).

As illustrated in FIG. 25, base stations 2520, 2524, 2596 operate to connect telephones together via telephone networks 2522, satellites 2526, or other communication mediums, such as but not limited to data networks (such as the Internet). Also, the base stations 2520, 2524, enable telephones (such as cellular telephones 2508, 2512) to communicate with each other via a base station 2520 and not through a network or other intermediate communication medium. This is illustrated, for example, by dotted data flow line 2528.

The invention is directed to all types of base stations, such as macro base stations (operating in networks that are relatively large), micro base stations (operating in networks that are relatively small), satellite base stations (operating



with satellites), cellular base stations (operating in a cellular telephone networks), data communication base stations (operating as gateways to computer networks), etc.

#### Positioning

The invention is directed to positioning devices that enable the determination of the location of an object.

FIG. 26 illustrates an example positioning unit 2608 according to an embodiment of the invention. The positioning unit 2608 includes a receiver 2610 for receiving positioning information from satellites, such as satellites 2604, 2606. Such positioning information is processed in a well known manner by a positioning module 2614 to determine the location of the positioning unit 2608. Preferably, the receiver 2610 is implemented using a UFT module for performing frequency down-conversion operations (see, for example, FIG. 7).

The positioning unit 2608 may include an optional transmitter 2612 for transmitting commands and/or other information to satellites 2604, 2606, or to other destinations. In an embodiment, the transmitter 2612 is implemented using a UFT module for performing frequency up-conversion operations (see, for example, FIG. 8).

In an embodiment, the receiver 2610 and the optional transmitter 2612 are replaced in the positioning unit 2608 by a transceiver which includes one or more UFT modules (see, for example, FIGS. 10 and 11).

The invention is directed to all types of positioning systems, such as but not limited to global positioning systems (GPS), differential GPS, local GPS, etc.

#### Data Communication

The invention is directed to data communication among data processing devices. For example, and without limitation, the invention is directed to computer networks (such as, for example, local area networks and wide area networks), modems, etc.

FIG. 27 illustrates an example environment 2702 wherein computers 2704, 2712, and 2726 are communicating with one another via a computer network 2734. In the example of FIG. 27, computer 2704 is communicating with the network 2734 via a wired link, whereas computers 2712 and 2726 are communicating with the network 2734 via wireless links.

In the teachings contained herein, for illustrative purposes, a link may be designated as being a wired link or a wireless link. Such designations are for example purposes only, and are not limiting. A link designated as being wireless may alternatively be wired. Similarly, a link designated as being wired may alternatively be wireless. This is applicable throughout the entire application.

The computers 2704, 2712 and 2726 each include an interface 2706, 2714, and 2728, respectively, for communicating with the network 2734. The interfaces 2706, 2714, and 2728 include transmitters 2708, 2716, and 2730 respectively. Also, the interfaces 2706, 2714 and 2728 include receivers 2710, 2718, and 2732 respectively. In embodiments of the invention, the transmitters 2708, 2716 and 2730 are implemented using UFT modules for performing frequency up-conversion operations (see, for example, FIG. 8). In embodiments, the receivers 2710, 2718 and 2732 are implemented using UFT modules for performing frequency down-conversion operations (see, for example, FIG. 7).

As noted above, the computers 2712 and 2726 interact with the network 2734 via wireless links. In embodiments of the invention, the interfaces 2714, 2728 in computers 2712, 2726 represent modems.

In embodiments, the network 2734 includes an interface or modem 2720 for communicating with the modems 2714, 2728 in the computers 2712, 2726. In embodiments, the

interface 2720 includes a transmitter 2722, and a receiver 2724. Either or both of the transmitter 2722, and the receiver 2724 are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

In alternative embodiments, one or more of the interfaces 2706, 2714, 2720, and 2728 are implemented using transceivers that employ one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11).

FIG. 28 illustrates another example data communication embodiment 2802. Each of a plurality of computers 2804, 2812, 2814 and 2816 includes an interface, such as an interface 2806 shown in the computer 2804. It should be understood that the other computers 2812, 2814, 2816 also include an interface such as an interface 2806. The computers 2804, 2812, 2814 and 2816 communicate with each other via interfaces 2806 and wireless or wired links, thereby collectively representing a data communication network.

The interfaces 2806 may represent any computer interface or port, such as but not limited to a high speed internal interface, a wireless serial port, a wireless PS2 port, a wireless USB port, etc.

The interface 2806 includes a transmitter 2808 and a receiver 2810. In embodiments of the invention, either or both of the transmitter 2808 and the receiver 2810 are implemented using UFT modules for frequency up-conversion and down-conversion (see, for example, FIGS. 7 and 8). Alternatively, the interfaces 2806 can be implemented using a transceiver having one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11).

#### Pagers

The invention is directed to pagers that employ UFT modules for performing frequency translation operations.

FIG. 29 illustrates an example pager 2902 according to an embodiment of the invention. Pager 2902 includes a receiver 2906 for receiving paging messages. In embodiments of the invention, the receiver 2906 is implemented using a UFT module for performing frequency down-conversion operations (see, for example, FIG. 7).

The pager 2902 may also include a transmitter 2908 for sending pages, responses to pages, or other messages. In embodiments of the invention, the transmitter 2908 employs a UFT module for performing up-conversion operations (see, for example, FIG. 8).

In alternative embodiments of the invention, the receiver 2906 and the transmitter 2908 are replaced by a transceiver that employs one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11).

The pager 2902 also includes a display 2904 for displaying paging messages. Alternatively, or additionally, the pager 2902 includes other mechanisms for indicating the receipt of a page such as an audio mechanism that audibly indicates the receipt of a page, or a vibration mechanism that causes the pager 2902 to vibrate when a page is received.

The invention is directed to all types of pagers, such as and without limitation, one way pagers, two way pagers, etc. FIG. 30 illustrates a one way pager 3004 that includes a receiver 3006. The one way pager 3004 is capable of only receiving pages. In the scenario of FIG. 30, the one way pager 3004 receives a page 3005 from an entity which issues pages 3008. The one way pager 3004 includes a receiver 3006 that is implemented using a UFT module for performing frequency down-conversion operations (see, for example, FIG. 7).

FIG. 30 also illustrates a two way pager 3010. The two way pager 3010 is capable of receiving paging messages and of transmitting pages, responses to paging messages, and/or other messages. The two way pager 3010 includes a receiver 3012 for receiving messages, and a transmitter 3014 for transmitting messages. One or both of the receiver 3012 and the transmitter 3014 may be implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8). Alternatively, the receiver 3010 and the transmitter 3014 can be replaced by a transceiver that employs one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11).

Security  
The invention is directed to security systems having components which are implemented using UFT modules for performing frequency translation operations. FIG. 31 illustrates an example security system 3102 which will be used to describe this aspect of the invention.

The security system 3102 includes sensors which sense potential intrusion/hazard events, such as the opening of a window, the opening of a door, the breakage of glass, motion, the application of pressure on floors, the disruption of laser beams, fire, smoke, carbon monoxide, etc. Upon detecting an intrusion/hazard event, the sensors transmit an intrusion/hazard event message to a monitor panel 3116 that includes a monitor and alarm module 3120. The monitor and alarm module 3120 processes intrusion/hazard event messages in a well known manner. Such processing may include, for example, sending messages via a wired link 3134 or a wireless link 3136 to a monitoring center 3130, which may in turn alert appropriate authorities 3132 (such as the police, the fire department, an ambulance service, etc.).

FIG. 31 illustrates a one way sensor 3109 that is positioned, for example, to detect the opening of a door 3106. The one way sensor 3109 is not limited to this application, as would be apparent to persons skilled in the relevant arts. The one way sensor 3109 includes contacts 3108 and 3110 that are positioned on the door 3106 and the frame 3104 of the door 3106. When the contacts 3108 and 3110 are displaced from one another, indicating the opening of the door 3106, a transmitter 3112 contained in the contact 3110 transmits an intrusion/hazard event message 3114 to the monitor panel 3116.

In an embodiment, the one way sensor 3109 also transmits status messages to the monitor panel 3116. Preferably, these status messages are transmitted during a time period that is assigned to the one way sensor 3109. The status messages include information that indicates the status of the one way sensor 3109, such as if the sensor 3109 is operating within normal parameters, or if the sensor 3109 is damaged in some way. The monitor panel 3116, upon receiving the status messages, takes appropriate action. For example, if a status message indicates that the sensor 3109 is damaged, then the monitor panel 3116 may display a message to this effect, and/or may transmit a call for service. If the monitor panel 3116 does not receive a status message from the one way sensor 3109 in the time period assigned to the one way sensor 3109, then the monitor panel 3116 may issue an alarm indicating a potential intrusion or other breach in perimeter security.

Preferably, the transmitter 3112 is implemented using a UFT module to perform frequency up-conversion operations (see, for example, FIG. 8).

The one way sensor 3109 is capable of only transmitting. The invention is also directed to two way sensors, an example of which is shown as 3125. The two way sensor

3125 is shown in FIG. 31 as being positioned to detect the opening of a door 3138. The two way sensor 3125 is not limited to this application, as would be apparent to persons skilled in the relevant arts.

The two way sensor 3125 includes contacts 3124 and 3126 for detecting the opening of the door 3138. Upon detection of the opening of the door 3138, a transceiver 3128 in contact 3126 sends an intrusion/hazard event message to the monitor panel 3116. Preferably, the transceiver 3128 is implemented using one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11). Alternatively, the two way sensor 3125 may employ a receiver and a transmitter, wherein one or both of the receiver and transmitter includes UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

The two way sensor 3125 is capable of both receiving and transmitting messages. Specifically, as just discussed, the transceiver 3128 in the two way sensor 3125 sends intrusion/hazard event messages to the monitor panel 3116. Additionally, the two way sensor 3125 may receive commands or other messages (such as polls) from the monitor panel 3116 via the transceiver 3128.

In an embodiment, the two way sensor 3125 also transmits status messages to the monitor panel 3116. In an embodiment, these status messages are transmitted during a time period that is assigned to the two way sensor 3125. The nature of these status message is described above.

In an alternative embodiment, the monitor panel 3116 polls for status messages. When the two way sensor 3125 receives an appropriate polling message, it transmits its status message to the monitor panel 3116. If the monitor panel 3116 does not receive a status message in response to a polling message, then it may issue an alarm indicating a potential intrusion or other breach in perimeter security.

The monitor panel 3116 includes a transceiver 3118 for communicating with sensors, such as sensors 3109 and 3125, and for also communicating with external entities, such as monitoring center 3130, appropriate authorities 3132, etc. The transceiver 3118 is preferably implemented using one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11). Alternatively, the transceiver 3118 may be replaced by a receiver and a transmitter, wherein one or both of the receiver and transmitter is implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

In an embodiment, the monitor panel 3116 communicates with the monitoring center 3130 via a wired telephone line 3134. However, communication over the telephone line 3134 may not always be possible. For example, at times, the telephone line 3134 may be inoperative due to natural events, failure, maintenance, sabotage, etc. Accordingly, embodiments of the invention include a back-up communication mechanism. For example, in FIG. 31, the monitor panel 3116 includes a cellular phone backup system for communication with the monitoring center 3130. This wireless link between the monitor panel 3116 and the monitoring center 3130 is represented by dotted line 3136. The transceiver 3118 (or perhaps another transceiver contained in the monitoring panel 3116 or located proximate thereto) communicates with the monitor center 3130 via the wireless link 3136. As noted, the transceiver 3118 is preferably implemented using one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11).

## Repeaters

The invention is directed to communication repeaters which, generally, receive a signal, optionally amplify the signal, and then transmit the amplified signal at the same or different frequency or frequencies. A repeater is often used in combination with one or more other repeaters to transmit a signal from a first point to a second point, where the first and second points are widely spaced from one another and/or are not in line of sight with one another.

This is illustrated, for example, in FIG. 32, where a signal is being transmitted from a station 3204 to another station 3218, where stations 3204, 3218 are separated by a mountain. Signals from station 3204 are sent to station 3218 via repeaters 3206, 3208, and 3210. Similarly, signals from station 3218 are sent to station 3204 via repeaters 3206, 3208, and 3210.

Each of the repeaters 3206, 3208, 3210 includes a transceiver 3212, 3214, 3216, respectively. In embodiments of the invention, the transceivers 3212, 3214, 3216 are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11). Alternatively, the transceivers 3212, 3214, 3216 may be replaced by receivers and transmitters, wherein the receivers and transmitters are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

The invention includes all types of repeaters. For example, the repeater scenario described above represents a long distance or long range use of repeaters (for example, macro use). The invention is also applicable to short distance use of repeaters (for example, micro use). An example of this is shown in FIG. 32, where a repeater 3252 having a transceiver 3254 is positioned in a building or home 3250. The repeater 3252 relays signals from a cell phone 3256 or other communication device (such as a computer with a modem, a television with an input for programming, a security system, a home control system, etc.) to a base station 3218 and/or another repeater 3210. In the example scenario of FIG. 32, the combination of the cell phone 3256 and the repeater 3252 is generally similar to a cordless telephone. In embodiments of the invention, the transceivers 3254, 3258 are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11). Alternatively, the transceivers 3254, 3258 may be replaced by receivers and transmitters, wherein the receivers and transmitters are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

## Mobile Radios

The invention is directed to mobile radios that use UFT modules for performing frequency translation operations. The invention is applicable to all types of mobile radios operating in any and all bands for any and all services, such as but not limited to walkie-talkies, citizen band, business, ISM (Industrial Scientific Medical), amateur radio, weather band, etc. See FIGS. 42A-42D for example frequency bands operable with the present invention (the invention is not limited to these bands).

FIG. 33 illustrates an example scenario 3302 where a first mobile radio 3304 is communicating with a second mobile radio 3306. Each of the mobile radios 3304, 3306 includes a transmitter 3308, 3312 and a receiver 3310, 3314, respectively. The transmitter 3308, 3312, and/or the receivers 3310, 3314 are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8). Alternatively, the transmitters 3308, 3312 and the receivers 3310, 3314 can be replaced by transceivers

which utilize one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11).

The invention is also directed to receive-only radios, such as the radio 4402 shown in FIG. 44. The radio 4402 includes a receiver 4404 to receive broadcasts. The radio 4402 also includes a speaker 4406 and other well known radio modules 4408. The radio 4402 may work in any band, such as but not limited to AM, FM, weather band, etc. See FIGS. 42A-42D for an example of the bands. The receiver 4404 is preferably implemented using a UFT module (see, for example, FIG. 7).

## Satellite Up/Down Links

The invention is directed to systems and methods for communicating via satellites. This includes, for example, direct satellite systems (DSS), direct broadcast satellite (DBS), ultra wideband public/private services, etc.

FIG. 34 illustrates an example environment 3402 where content transmitted from a content provider 3420 is received by a private home 3404 via a satellite 3416. A satellite unit 3408 is located in the home 3404. The satellite unit 3408 includes a receiver 3410 for receiving signals from the satellite 3416 and a transmitter 3412 for transmitting signals to the satellite 3416.

In operation, the content provider 3420 transmits content to the satellite 3416, which then broadcasts that content. The content is received at the home 3404 by an antenna or satellite dish 3414. The received signals are provided to the receiver 3410 of the satellite unit 3408, which then down-converts and demodulates, as necessary, the signal. The data is then provided to a monitor 3406 for presentation to the user. The monitor 3406 may be any device capable of receiving and displaying the content from the content provider 3420, such as a TV, a computer monitor, etc.

In embodiments of the invention, the receiver 3410 and/or the transmitter 3412 are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8). In other embodiments, the receiver 3410 and the transmitter 3412 are replaced by a transceiver which employs one or more UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11).

The satellite unit 3408 can be used to send and receive large amounts of data via ultra wide band satellite channels. For example, in addition to receiving content from the content provider, it is possible to use the satellite unit 3408 to exchange data with other locations 3418 via the satellite links provided by satellites (such as satellite 3416).

## Command and Control

The invention is directed to command and control applications. Example command and control applications are described below for illustrative purposes. The invention is not limited to these examples.

## PC Peripherals

The present invention is directed to computer peripherals that communicate with a computer over a wireless communication medium. FIG. 35 illustrates an example computer 3502 which includes a number of peripherals such as but not limited to a monitor 3506, a keyboard 3510, a mouse 3514, a storage device 3518, and an interface/port 3522. It should be understood that the peripherals shown in FIG. 35 are presented for illustrative purposes only, and are not limiting. The invention is directed to all devices that may interact with a computer.

The peripherals shown in FIG. 35 interact with a computer 3502 via a wireless communication medium. The computer 3502 includes one or more transceivers 3504 for

communicating with peripherals. Preferably, the transceivers **3504** are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. **10** and **11**). Alternatively, the transceiver **3504** in the computer **3502** may be replaced by receivers and transmitters, wherein any of the receivers and transmitters are implemented by using UFT modules for performing frequency translation operations (see, for example, FIGS. **7** and **8**).

Each of the peripherals includes a transceiver for communicating with the computer **3502**. In embodiments of the invention, the transceivers are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. **10** and **11**). In other embodiments, the transceivers are replaced by receivers and transmitters which are implemented by UFT modules for performing frequency translation operations (see, for example, FIGS. **7** and **8**).

The computer **3502** may send a signal to the peripherals that indicates that it is receiving signals from the peripherals. The peripherals could then provide an indication that a link with the computer **3502** is established (such as, for example, turning a green light on).

In some embodiments, some peripherals may be transmit-only, in which case they would include a transmitter instead of a transceiver. Some peripherals which may be transmit only include, for example, the keyboard **3510**, the mouse **3514**, and/or the monitor **3506**. Preferably, the transmitter is implemented using a UFT module for performing frequency up-conversion operations (see, for example, FIG. **8**).

#### Building/Home Functions

The invention is directed to devices for controlling home functions. For example, and without limitation, the invention is directed to controlling thermostats, meter reading, smart controls, including C-Bus and X-**10**, garage door openers, intercoms, video rabbits, audio rabbits, etc. These examples are provided for purposes of illustration, and not limitation. The invention includes other home functions, appliances, and devices, as will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

FIG. **36** illustrates an example home control unit **3604**. The home control unit **3604** includes one or more transceivers **3606** for interacting with remote devices. In embodiments of the invention, the transceivers **3606** are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. **10** and **11**). In other embodiments, the transceivers **3606** are replaced by receivers and transmitters that employ UFT modules for performing frequency translation operations (see, for example, FIGS. **7** and **8**). In some embodiments, the home control unit **3604** can be transmit only, in which case the transceiver **3606** is replaced by a transmitter which is preferably implemented using a UFT module.

The home control unit **3604** interacts with remote devices for remotely accessing, controlling, and otherwise interacting with home functional devices. For example, the home control unit **3604** can be used to control appliances **3608** such as, but not limited to, lamps, televisions, computers, video recorders, audio recorders, answering machines, etc. The appliances **3608** are coupled to one or more interfaces **3610**. The interfaces **3610** each includes a transceiver **3612** for communicating with the home control **3604**. The transceiver **3612** includes one or more UFT modules for performing frequency translation operations (see, for example, FIGS. **10** and **11**). Alternatively, the interfaces **3610** each includes a receiver and a transmitter, either or both of which

include UFT modules for performing frequency translation operations (see, for example, FIGS. **7** and **8**).

The home control unit **3604** can also remotely access and control other home devices, such as a thermostat **3618** and a garage door opener **3614**. Such devices which interact with the home control unit **3604** include transceivers, such as transceiver **3620** in the thermostat **3618**, and transceiver **3616** in the garage opener **3614**. The transceivers **3620,3616** include UFT modules for performing frequency translation operations (see, for example, FIGS. **10** and **11**). Alternatively, the transceivers **3616, 3620** can be replaced by receivers and transmitters for performing translation operations (see, for example, FIGS. **7** and **8**).

The invention is also directed to the control of home electronic devices, such as but not limited to televisions, VCRs, stereos, CD players, amplifiers, tuners, computers, video games, etc. For example, FIG. **36** illustrates a television **3650** and a VCR **3654** having receivers **3652, 3656** for receiving control signals from remote control(s) **3658**, where each of the remote control(s) **3658** includes a transmitter **3660**. The receivers **3652, 3656** are preferably implemented using UFT modules (see, for example, FIG. **7**), and the transmitter **3660** is preferably implemented using a UFT module (see, for example, FIG. **8**).

In some cases, it may be necessary to install an adapter **3666** to enable a device to operate with remote control(s) **3658**. Consider a stereo **3662** having an infrared receiver **3664** to receive infrared control signals. Depending on their implementation, some embodiments of the remote control(s) **3658** may not transmit signals that can be accurately received by the infrared receiver **3664**. In such cases, it is possible to locate or affix a receiver **3668** (preferably implemented using a UFT module) and an adapter **3666** to the stereo **3662**. The receiver **3668** operates to receive control signals from the remote control(s) **3658**. The adapter **3666** converts the received signals to signals that can be received by the infrared receiver **3664**.

The invention can also be used to enable the remote access to home control components by external entities. For example, FIG. **37** illustrates a scenario **3702** where a utility company **3704** remotely accesses a utility meter **3710** that records the amount of utilities used in the home **3708**. The utility company **3704** may represent, for example, a service vehicle or a site or office. The utility meter **3710** and the utility company **3704** include transceivers **3712, 3706**, respectively, for communicating with each other. Preferably, the transceivers **3706,3712** utilize UFT modules for performing frequency translation operations (see, for example, FIGS. **10** and **11**). Alternatively, the transceivers **3706,3712** are replaced by receivers and transmitters, wherein the receivers and/or transmitters are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. **7** and **8**).

The invention is also directed to other home devices. For example, and without limitation, the invention is directed to intercoms. As shown in FIG. **38**, intercoms **3804, 3806** include transceivers **3808, 3810**, respectively, for communicating with other. In embodiments of the invention, the transceivers **3808,3810** include UFT modules for performing frequency translation operations (see, for example, FIGS. **10** and **11**). In other embodiments, the transceivers **3808, 3810** are replaced by receivers and transmitters, wherein the receivers and/or transmitters are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. **7** and **8**).

The invention can also be used to transmit signals from one home device to another home device. For example, the

invention is applicable for propagating video and/or audio signals throughout a home. This is shown, for example, in FIG. 38, where TVs 3812, 3814 include transceivers 3816, 3818 for communicating with one another. The transceivers 3816, 3818 enabled video signals to be sent from one of the TVs to another. In embodiments of the invention, the transceivers 3816, 3818 are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11). In other embodiments, the transceivers 3816, 3818 are replaced by receivers and transmitters, wherein the receivers and/or transmitters are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

FIG. 38 also illustrates an embodiment where transceivers 3824, 3826 are used to communicate audio signals between a CD player 3820 and a multi-media receiver 3822. In embodiments, the transceivers 3824, 3826 are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 10 and 11). In other embodiments, the transceivers 3824, 3826 are replaced by receivers and transmitters, wherein the receivers and/or transmitters are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

In the figures described above, many of the components are shown as including transceivers. In practice, however, some components are receive only or transmit only. This is true for some of the devices discussed throughout this application, as will be apparent to persons skilled in the relevant art(s). In such cases, the transceivers can be replaced by receivers or transmitters, which are preferably implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

#### Automotive Controls

The invention is directed to automotive controls, and other devices of ten used in or with automobiles.

FIG. 39 illustrates an example car 3902 according to an embodiment of the invention. The car 3902 includes a number of devices that communicate with objects.

For example, the car 3902 includes an interface 3904 (or multiple interfaces) for communicating with external devices, such as but not limited to gasoline pumps 3912 and toll booths 3916. In operation, for example, when the car 3902 approaches the toll booth 3916, the interface 3904 communicates with the toll booth 3916 in an appropriate and well known manner to enable the car 3902 to pass through the toll booth 3916. Also, when the car 3902 is proximate to the gasoline pump 3912, the interface 3904 interacts with the gas pump in an appropriate and well known manner to enable the driver of the car 3902 to utilize the gas pump 3912 to fill the car 3902 with gas.

The car also includes a controllable door lock 3908. Upon receipt of an appropriate signal from a keyless entry device 3914, the controllable door lock 3908 locks or unlocks (based on the signal received).

The car further includes a controller 3910, which controls and interacts with the systems, instrumentation, and other devices of the car 3902. The controller 3910 communicates with a control unit 3918. It is possible to control the car 3902 via use of the control unit 3918. The control unit 3918 sends commands to the controller 3910. The controller 3910 performs the functions specified in the commands from the control unit 3918. Also, the control unit 3918 sends queries to the controller 3910. The controller 3910 transmits to the control unit 3918 the car-related information specified in the queries. Thus, any car functions under the control of the controller 3910 can be controlled via the control unit 3918.

It is noted that the features and functions described above and shown in FIG. 39 are provided for illustrative purposes only, and are not limiting. The invention is applicable to other car related devices, such as but not limited to security systems, GPS systems, telephones, etc.

The interface 3904, the door lock 3908, the controller 3910, and any other car devices of interest include one or more transceivers 3906A, 3906B, 3906C for communicating with external devices. Also, the gasoline pump 3912, keyless entry device 3914, toll booth 3916, control unit 3918, and any other appropriate devices include transceivers 3906D, 3906E, 3906F, 3906G for communicating with the car 3902.

Preferably, the transceivers 3906 are implemented using UFT modules for performing frequency translation operations (see FIGS. 10 and 11). Alternatively, one or more of the transceivers 3906 can be replaced by receiver(s) and/or transmitter(s), wherein the receiver(s) and/or transmitter(s) are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

#### Aircraft Controls

The invention is directed to aircraft controls, and other devices of ten used in or with aircrafts.

FIG. 40A illustrates an example aircraft 4002 according to an embodiment of the invention. The aircraft 4002 includes, for example, a GPS unit 4012 for receipt of positioning information. The GPS unit 4012 is coupled to a transceiver 4004D for receiving positioning information.

The aircraft 4002 also includes one or more radio(s) 4010 for communication with external entities. The radio(s) 4010 include one or more transceivers 4004C for enabling such communication.

The aircraft 4002 also includes monitors 4008 for displaying, for example, video programming, and computers 4009 that transmit and receive information over a communication network. The monitors 4008 and computers 4009 include one or more transceiver(s) 4004B for communicating with external devices, such as video programming sources and/or data communication networks.

The aircraft 4002 includes a controller 4006 for controlling the systems, instrumentation, and other devices of the aircraft 4002. The controller 4006 can communicate with external devices via a transceiver 4004A. External devices may control the aircraft 4002 by sending appropriate commands, queries, and other messages to the controller 4006.

It is noted that the features and functions described above and shown in FIG. 40A are provided for illustrative purposes only, and are not limiting. The invention is applicable to other aircraft related devices, such as but not limited to security systems, telephones, etc.

Preferably, the transceivers 4004 are implemented using UFT modules for performing frequency translation operations (see FIGS. 10 and 11). Alternatively, one or more of the transceivers 4004 can be replaced by receiver(s) and/or transmitter(s), wherein the receiver(s) and/or transmitter(s) are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

#### Maritime Controls

The invention is directed to maritime controls, and other maritime-related devices.

FIG. 40B illustrates an example boat 4050 according to an embodiment of the invention. The devices in the example boat 4050 of FIG. 40B are similar to the devices in the example aircraft 4002 of FIG. 40A. Accordingly, the description above relating to FIG. 40A applies to FIG. 40B.

## Radio Control

The invention is directed to radio controlled devices, such as but not limited to radio controlled cars, planes and boats.

FIG. 41 illustrates radio controlled devices according to embodiments of the invention. A controller 4104 includes control logic 4106 for generating commands to control various devices, such as a plane 4110, a car 4116, and a boat 4122. The controller 4104 includes a transceiver 4108 for communication with the plane 4110, car 4146, and boat 4122.

The plane 4110, the car 4116, and the boat 4122 includes control modules 4112, 4118 and 4124 for processing commands received from the controller 4104. Also, control modules 4112, 4118, and 4124 maintain status information that can be communicated back to the control 4104. The plane 4110, the car 4116 and boat 4122 include transceivers 4114, 4120, and 4126, respectively, for communicating with the controller 4104.

Preferably, the transceivers 4108, 4114, 4120, and 4126 are implemented using UFT modules for performing frequency translation operations (see FIGS. 10 and 11). Alternatively, the transceivers 4108, 4114, 4120, and 4126 can be replaced by receivers and transmitters, wherein the receivers and/or transmitters are implemented using UFT modules for performing frequency translation operations (see, for example, FIGS. 7 and 8).

## Radio Synchronous Watch

The invention is directed to radio synchronous time devices. Radio synchronous time devices are time pieces that receive signals representative of the current time. An example source of such time signals is radio station WWV in Boulder, Colo. Radio synchronous time devices update their internal clocks with the current time information contained in the signals.

The invention is directed to all types of radio synchronous time devices, such as alarm clocks, clocks in appliances and electronic equipment such as clocks in computers, clocks in televisions, clocks in VCRs, wrist watches, home and office clocks, clocks in ovens and other appliances, etc.

FIG. 43 illustrates an example radio synchronous time piece 4302, an example of which is shown in FIG. 43. The radio synchronous time piece 4302 includes a display 4304 to display the current time and time zone (and perhaps the position of the time piece 4302), receiver(s) 4306, a time module 4310, a GPS module 4308, and a battery 4312.

The receiver 4306 receives time signals from a time information source 4314. Based on the time signals, the time module 4310 determines the current time in a well known manner. Depending on the nature of the received time signals, the current time may be GMT. The current time is displayed in display 4304.

The receiver 4306 may receive the time signals continuously, periodically, upon user command, or sporadically (depending on the signal strength of the time information source 4314, for example). At times when the receiver 4306 is not receiving time signals, the time module 4310 determines the current time in a well known manner (i.e., the time module 4310 operates as a clock), using the indication of time in the last received time signal. In some embodiments, the time piece 4302 may provide some indication when it is receiving time signals from the time information source 4314. For example, the time piece 4302 may provide a visual or audible indication (such as lighting an LED or beeping when time signals are being received). The user can elect to disable this feature.

The receiver 4306 may also receive positioning information from global positioning satellites 4316. The GPS mod-

ule 4308 uses the received positioning information to determine the location of the time piece 4302. The time module 4310 uses the location information to determine the time zone and/or the local time. The time zone, the local time, and/or the location of the time piece 4302 may be displayed in the display 4304.

Preferably, the receiver(s) 4306 are implemented using UFT modules for performing frequency translation operations (see, for example, FIG. 7).

The invention is particularly well suited for implementation as a time piece given the low power requirements of UFT modules. Time pieces implemented using UFT modules increase the effective life of the battery 4312.

## Other Example Applications

The application embodiments described above are provided for purposes of illustration. These applications and embodiments are not intended to limit the invention. Alternate and additional applications and embodiments, differing slightly or substantially from those described herein, will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. For example, such alternate and additional applications and embodiments include combinations of those described above. Such combinations will be apparent to persons skilled in the relevant art(s) based on the herein teachings.

Additional applications and embodiments are described below.

## Applications Involving Enhanced Signal Reception

As discussed above, the invention is directed to methods and systems for enhanced signal reception (ESR). Any of the example applications discussed above can be modified by incorporating ESR therein to enhance communication between transmitters and receivers. Accordingly, the invention is also directed to any of the applications described above, in combination with any of the ESR embodiments described above.

## Applications Involving Unified Down-conversion and Filtering

As described above, the invention is directed to unified down-conversion and filtering (UDF). UDF according to the invention can be used to performed filtering and/or down-conversion operations.

Many if not all of the applications described herein involve frequency translation operations. Accordingly, the applications described above can be enhanced by using any of the UDF embodiments described herein.

Many if not all of the applications described above involve filtering operations. Accordingly, any of the applications described above can be enhanced by using any of the UDF embodiments described herein.

Accordingly, the invention is directed to any of the applications described herein in combination with any of the UDF embodiments described herein.

## Conclusion

Example implementations of the systems and components of the invention have been described herein. As noted elsewhere, these example implementations have been described for illustrative purposes only, and are not limiting. Other implementation embodiments are possible and covered by the invention, such as but not limited to software and software/hardware implementations of the systems and components of the invention. Such implementation embodiments will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

While various application embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only,

and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. An apparatus, comprising:

a universal frequency down-converter (UFD), including a switch, an integrator coupled to said switch, and a pulse generator coupled to said switch; and

wherein said pulse generator outputs to said switch at an aliasing rate that is determined according to:

(a frequency of a carrier signal +/- a frequency of a lower frequency signal) divided by N;

wherein said pulses have apertures and said causes switch to close and sub-sample the carrier signal over said apertures, and wherein energy is transferred from the carrier signal and integrated using said integrator during said apertures said pulses, and wherein the lower frequency signal is generated from the transferred energy; and

means for operating said UFD to perform at least frequency translation operations for at least one of (a)-(l);

- (a) a telephone;
- (b) a communication base station;
- (c) a positioning unit;
- (d) a data communication device;
- (d1) a communication network;
- (e) a pager;
- (f) a security system component;
- (g) a repeater;
- (h) a mobile radio;
- (i) a satellite communication system;
- (j) a command and control unit;
- (k) a radio controlled device; and
- (l) a radio synchronous time piece.

2. An apparatus, comprising:

at least one universal frequency down-conversion module, including a switch, an integrator coupled to said switch, and a pulse generator coupled to said switch; and

wherein said pulse generator outputs pulses to said switch at an aliasing rate that is determined according to:

(a frequency of a carrier signal +/- a frequency of a lower frequency signal) divided by N;

wherein said pulses have apertures and cause said switch to close and sub-sample the carrier signal over said apertures, and wherein energy is transferred from the carrier signal and integrated using said integrator during said apertures of said pulses, and wherein the lower frequency signal is generated from the transferred energy.

3. The apparatus of claim 2, further comprising:

at least one universal frequency up-conversion module.

4. The apparatus of claim 2, further comprising:

a positioning unit that receives positioning information from at least one satellite to determine the location of an object, said positioning unit comprising said at least one universal frequency down-conversion module.

5. The apparatus of claim 4, wherein said positioning unit further comprises at least one universal frequency up-conversion module.

6. The apparatus of claim 2, wherein said apparatus represents a pager.

7. The apparatus of claim 6, wherein said apparatus further comprises at least one universal frequency up-conversion module.

8. The apparatus of claim 2, wherein said apparatus represents a mobile radio.

9. The apparatus of claim 8, wherein said apparatus further comprises at least one universal frequency up-conversion module.

10. The apparatus of claim 2, further comprising:

a peripheral device comprising said at least one universal frequency up-conversion module;

whereby said peripheral device communicates via a wireless medium with a computer through an interface comprising at least one universal frequency down-conversion module, whereby said interface is coupled to the computer.

11. The apparatus of claim 10, wherein said peripheral device is a mouse, a keyboard, a monitor, or a storage device.

12. The apparatus of claim 2, wherein said apparatus represents a wireless interface for a home device.

13. The apparatus of claim 12, wherein the home device is a lamp, a television, a computer, a video recorder, an audio recorder, or an answering machine.

14. The apparatus of claim 2, wherein said apparatus represents a home electronic device that can be remotely accessed and controlled.

15. The apparatus of claim 14, wherein said home electronic device is a lamp, a television, a computer, a video recorder, an audio recorder, an answering machine, a thermostat, a garage door opener, a stereo, a CD player, an amplifier, a tuner, a video game, or a wireless home device adaptor.

16. The apparatus of claim 14, further comprising at least one universal frequency up-conversion module.

17. The apparatus of claim 2, wherein said apparatus represents a global positioning system unit in an aircraft.

18. The apparatus of claim 2, wherein said apparatus represents a global positioning system unit in a boat.

19. The apparatus of claim 2, further comprising:

a time piece that comprises

a receiver that comprises said at least one universal frequency down-conversion module,

a time module that determines a current time from a first signal received by said receiver, and

a display that displays said determined current time;

whereby said apparatus represents a radio synchronous time device.

20. The apparatus of claim 19, wherein said time piece further comprises:

a global positioning system module that determines a location from a second signal received by said receiver, wherein said display displays said determined location.

21. The apparatus of claim 19, wherein said time piece is a computer clock, a television clock, a video cassette recorder clock, a wrist watch, a home clock, an office clock, an oven clock, or an appliance clock.

22. The apparatus of claim 2, wherein each of said at least one universal frequency down-conversion module comprises:

an energy transfer signal generator;

a switch module controlled by said energy transfer signal generator; and

a storage module coupled to said switch module.

23. The apparatus of claim 22, wherein said each of said at least one universal frequency down-conversion module further comprises:

an input impedance match circuit coupled to an input of said each of said at least one universal frequency down-conversion module.

24. The apparatus of claim 22, wherein said each of said at least one universal frequency down-conversion module further comprises:  
 an output impedance match circuit coupled to an output of said each of said at least one universal frequency down-conversion module. 5

25. The apparatus of claim 22, wherein said switch module is coupled between an input of said each of said at least one universal frequency down-conversion module and said storage module. 10

26. The apparatus of claim 22, wherein said each of said at least one universal frequency down-conversion module further comprises:  
 a tank circuit coupled between an input of said each of said at least one universal frequency down-conversion module and said switch module. 15

27. The apparatus of claim 22, wherein said each of said at least one universal frequency down-conversion module further comprises:  
 a feed forward circuit in parallel with said switch module. 20

28. The apparatus of claim 22, wherein said storage module is coupled between an input of said each of said at least one universal frequency down-conversion module and said switch module. 25

29. The apparatus of claim 22, wherein said each of said at least one universal frequency down-conversion module is tuned for at least one frequency greater than one Giga Hertz. 25

30. The apparatus of claim 22, wherein said each of said at least one universal frequency down-conversion module is tuned for at least one frequency between 10 Mega Hertz and 10 Giga Hertz. 30

31. The apparatus of claim 22, wherein said energy transfer signal generator comprises an asynchronous energy transfer signal generator.

32. The apparatus of claim 3, wherein each of said at least one universal frequency up-conversion module comprises:  
 a switch module that receives an oscillating signal, wherein said oscillating signal controls gating of said switch module to thereby generate a periodic signal having a plurality of harmonics; and  
 a filter coupled to said switch module to isolate at least one of said plurality of harmonics. 35

33. The apparatus of claim 32, wherein said switch module gates a bias signal, said bias signal being a function of an information signal, and wherein the amplitude of said periodic signal is a function of said bias signal. 45

34. The apparatus of claim 32, wherein said oscillating signal is a modulated oscillating signal, wherein said periodic signal is modulated substantially the same as said modulated oscillating signal, and wherein each of said plurality of harmonics is modulated substantially the same as said periodic signal. 50

35. The apparatus of claim 34, wherein said modulated oscillating signal is a function of a first information signal, wherein said switch module gates a bias signal, wherein said bias signal is a function of a second information signal, and wherein the amplitude of said periodic signal is a function of said bias signal. 55

36. The apparatus of claim 3, further comprising:  
 a handset comprising said at least one first universal frequency up-conversion module and said at least one first universal frequency down-conversion module; and  
 a base unit that communicates with said handset via wireless links, said base unit comprising at least one second universal frequency up-conversion module and at least one second universal frequency down-conversion module; 60

whereby said apparatus represents a cordless telephone apparatus.

37. The apparatus of claim 3, further comprising:  
 a telephone comprising said at least one universal frequency up-conversion module and said at least one universal frequency down-conversion module.

38. The apparatus of claim 37, wherein said telephone is a cellular telephone or a satellite telephone.

39. The apparatus of claim 3, further comprising:  
 a base station that interfaces with telephones via wireless links, said base station comprising said at least one universal frequency up-conversion module and said at least one universal frequency down-conversion module. 10

40. The apparatus of claim 3, further comprising:  
 a network; and  
 an interface coupled to said network, whereby said interface connects data processing devices to said network via wireless links, said interface comprising said at least one universal frequency up-conversion module and said at least one universal frequency down-conversion module; 15

whereby said apparatus represents a data communication network.

41. The apparatus of claim 3, further comprising:  
 a monitor panel comprising  
 said at least one first universal frequency up-conversion module, and  
 said at least one universal frequency down-conversion module; and  
 at least one sensor that transmits intrusion/hazard event signals to said monitor panel, each of said at least one sensor comprising at least one second universal frequency up-conversion module; 20

whereby said apparatus represents a security system.

42. The apparatus of claim 3, wherein said apparatus represents a repeater.

43. The apparatus of claim 3, wherein said apparatus represents a satellite unit. 25

44. The apparatus of claim 3, further comprising:  
 a wireless home control unit that comprises said at least one universal frequency up-conversion module and said at least one universal frequency down-conversion module; 30

whereby said apparatus represents an apparatus for home control.

45. The apparatus of claim 44, wherein said wireless home control unit is a remote control unit.

46. The apparatus of claim 3, further comprising:  
 a home control unit that comprises said at least one universal frequency up-conversion module; and  
 a home electronic device that comprises said at least one first universal frequency down-conversion module, wherein said home electronic device communicates with said home control unit via a wireless medium; 35

whereby said apparatus represents a home control system.

47. The apparatus of claim 46, wherein said home control unit further comprises at least one second universal frequency down-conversion module.

48. The apparatus of claim 47, wherein said home electronic device further comprises at least one second universal frequency up-conversion module.

49. The apparatus of claim 48, wherein said home electronic device is a lamp, a television, a computer, a video recorder, an audio recorder, an answering machine, a 40



thermostat, a garage door opener, a stereo, a CD player, an amplifier, a tuner, a video game, or a wireless home device adaptor.

50. The apparatus of claim 49, wherein said home control unit is a remote control unit.

51. The apparatus of claim 3, wherein said apparatus is a wireless utility meter that communicates with a utility company, comprising:

said at least one first universal frequency up-conversion module; and

said at least one first universal frequency down-conversion module.

52. The apparatus of claim 3, further comprising:

a plurality of intercoms communicating with each other via a wireless medium, each of said plurality of intercoms comprising

said at least one universal frequency up-conversion module, and

said at least one universal frequency down-conversion module;

whereby said apparatus represents an intercom communication system.

53. The apparatus of claim 3, further comprising:

an interface that communicates with at least one external device via a wireless medium, said interface comprising

said at least one universal frequency down-conversion module, and

said at least one universal frequency up-conversion module;

whereby said apparatus represents an apparatus in an automobile for communicating with external devices.

54. The apparatus of claim 3, further comprising:

a device that communicates with an automobile communication interface via a wireless medium, said device comprising

said at least one universal frequency down-conversion module, and

said at least one universal frequency up-conversion module;

whereby said apparatus represents an apparatus for communicating with an automobile.

55. The apparatus of claim 54, wherein said device is a gasoline pump or a toll booth.

56. The apparatus of claim 3, further comprising:

a door lock that comprises

said at least one first universal frequency down-conversion module, and

said at least one first universal frequency up-conversion module; and

a keyless entry device that communicates with said door lock via a wireless medium, said keyless entry device comprising

at least one second universal frequency down-conversion module, and

at least one second universal frequency up-conversion module;

whereby said apparatus represents a controllable door lock apparatus.

57. The apparatus of claim 3, further comprising:

an automobile controller that comprises

said at least one first universal frequency down-conversion module, and

said at least one first universal frequency up-conversion module; and

a control unit that communicates with said automobile controller via a wireless medium, said control unit comprising

at least one second universal frequency down-conversion module, and

at least one second universal frequency up-conversion module;

whereby said apparatus represents an apparatus for controlling an automobile.

58. The apparatus of claim 3, wherein said apparatus represents an aircraft radio apparatus.

59. The apparatus of claim 3, wherein said apparatus represents a monitor in an aircraft.

60. The apparatus of claim 3, wherein said apparatus represents a computer in an aircraft.

61. The apparatus of claim 3, further comprising:

a aircraft controller that comprises

said at least one first universal frequency down-conversion module, and

said at least one first universal frequency up-conversion module; and

a control unit that communicates with said aircraft controller via a wireless medium, said control unit comprising

at least one second universal frequency down-conversion module, and

at least one second universal frequency up-conversion module;

whereby said apparatus represents an apparatus for controlling an aircraft.

62. The apparatus of claim 3, wherein said apparatus represents a boat radio apparatus.

63. The apparatus of claim 3, wherein said apparatus represents a monitor in a boat.

64. The apparatus of claim 3, wherein said apparatus represents a computer in a boat.

65. The apparatus of claim 3, further comprising:

a boat controller that comprises

said at least one first universal frequency down-conversion module, and

said at least one first universal frequency up-conversion module; and

a control unit that communicates with said boat controller via a wireless medium, said control unit comprising

at least one second universal frequency down-conversion module, and

at least one second universal frequency up-conversion module;

whereby said apparatus represents an apparatus for controlling a boat.

66. The apparatus of claim 3, further comprising:

a controller that comprises

said at least one universal frequency up-conversion module; and a radio controlled device that comprises

said at least one universal frequency down-conversion module;

whereby said apparatus represents an apparatus for radio control.

67. The apparatus of claim 66, wherein said controller further comprises at least one second universal frequency down-conversion module, and wherein said radio controlled device further comprises at least one second universal frequency up-conversion module.

68. The apparatus of claim 67, wherein said radio controlled device is a plane, a car, or a boat.

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 6,370,371 B1  
DATED : April 9, 2002  
INVENTOR(S) : Sorrells et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page.

Item [56], **References Cited**, U.S. PATENT DOCUMENTS, please add the following:

-- 5,841,811 --

FOREIGN PATENT DOCUMENTS, please add the following:

-- DE 35 41 031 A1

EP 0 732 803 A1 --

OTHER PUBLICATIONS, please add the following:

-- Fest, Jean-Pierre, "Le Convertisseur A/N Revolutionne Le Recepteur Radio,"  
*Electronique*, No. 54, December 1995, Paris, France, pp. 40-42.

Translation of DE Patent No. 35 41 031 A1, 22 pages.

Translation of EP Patent No. 0 732 803 A1, 9 pages.

Fest, Jean-Pierre, "The A/D Converter Revolutionizes the Radio Receiver,"  
*Electronique*, No. 54, December 1995, Paris, France, 3 pages. (Translation of Doc.  
AQ50). --

In the "Sabel, L.P.," reference, please replace "225" with -- 223 --.

Column 35.

Line 11, after "outputs" insert -- pulses --.

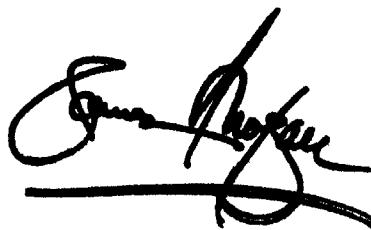
Line 15, change "said causes" to -- cause said --.

Line 18, after "apertures" insert -- of --.

Line 55, delete the second occurrence of "first".

Signed and Sealed this

Ninth Day of December, 2003



JAMES E. ROGAN  
Director of the United States Patent and Trademark Office