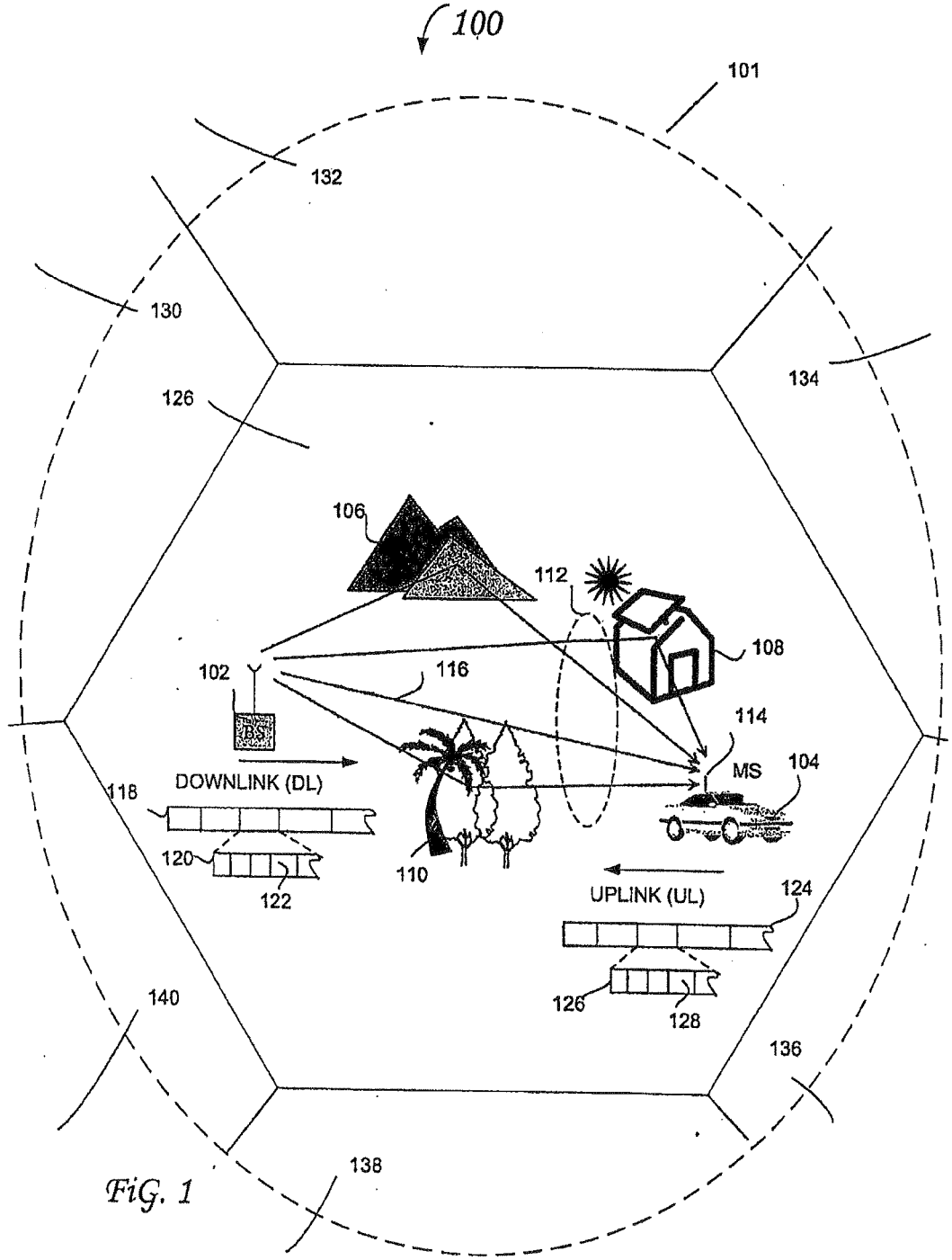
100
101
132
130
134
126
106
112
108
102
116
BS
114
MS
104
DOWNLINK (DL)
118
120
122
110
UPLINK (UL)
124
126
128
140
136
138

FiG. 1

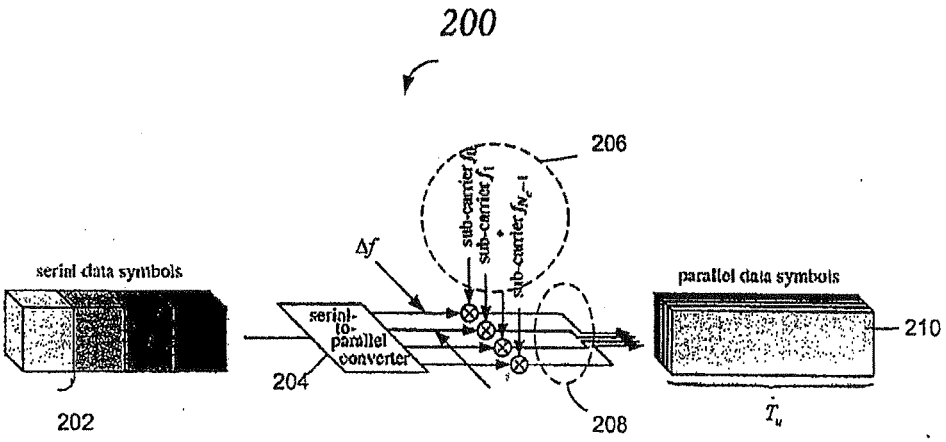
200
206
sub-carrier f_0
sub-carrier f_1
sub-carrier f_{N_c-1}
Δf
serial data symbols
serial-to-parallel converter
parallel data symbols
210
204
202
208
T_u

FIG. 2

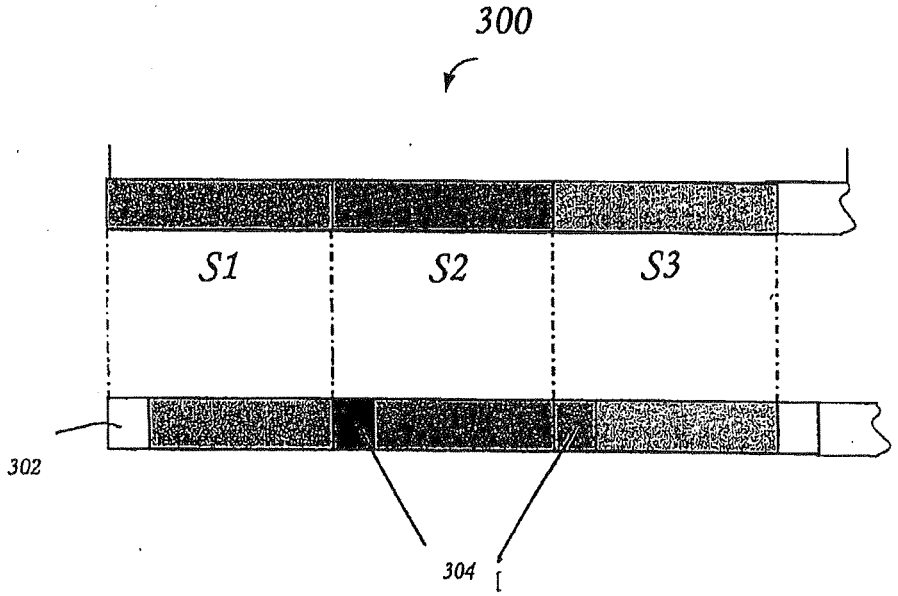
300
S1
S2
S3
302
304

FIG. 3

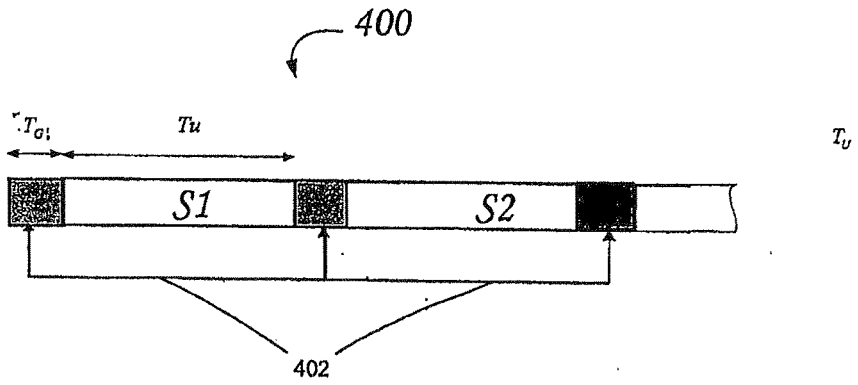
400
T_G
Tu
T_U
S1
S2
402

FIG. 4

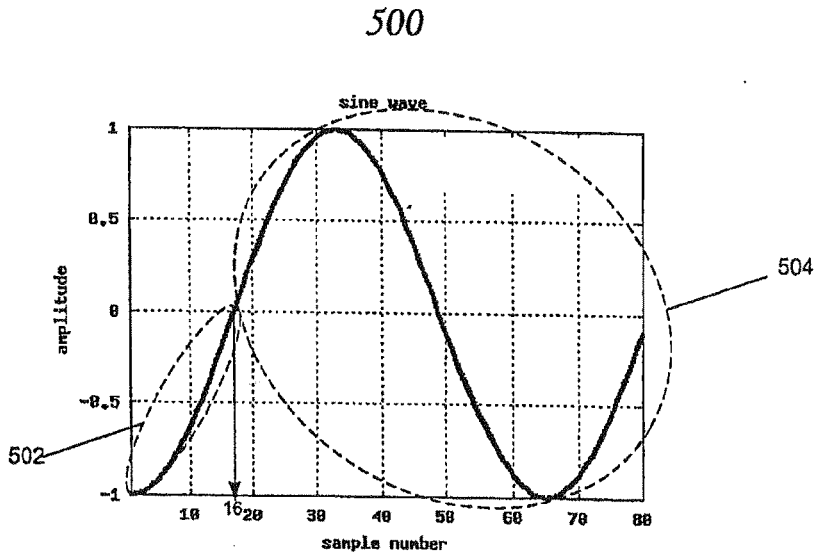
500
sine_wave
amplitude
sample number
1
0.5
0
-0.5
-1
10
16
20
30
40
50
60
70
80
502
504

FIG. 5

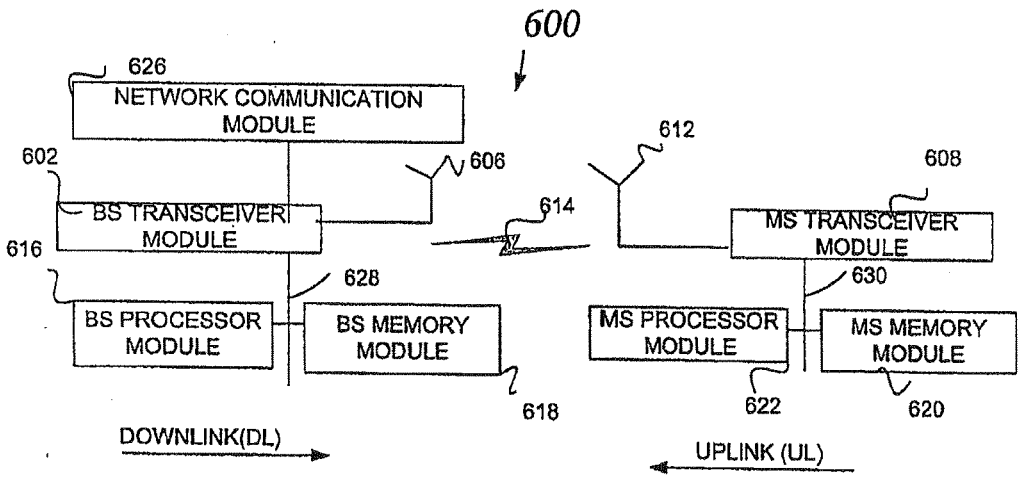
600
626
NETWORK COMMUNICATION MODULE
602
606
612
608
BS TRANSCEIVER MODULE
614
MS TRANSCEIVER MODULE
616
628
630
BS PROCESSOR MODULE
BS MEMORY MODULE
MS PROCESSOR MODULE
MS MEMORY MODULE
618
622
620
DOWNLINK(DL)
UPLINK (UL)

FIG. 6

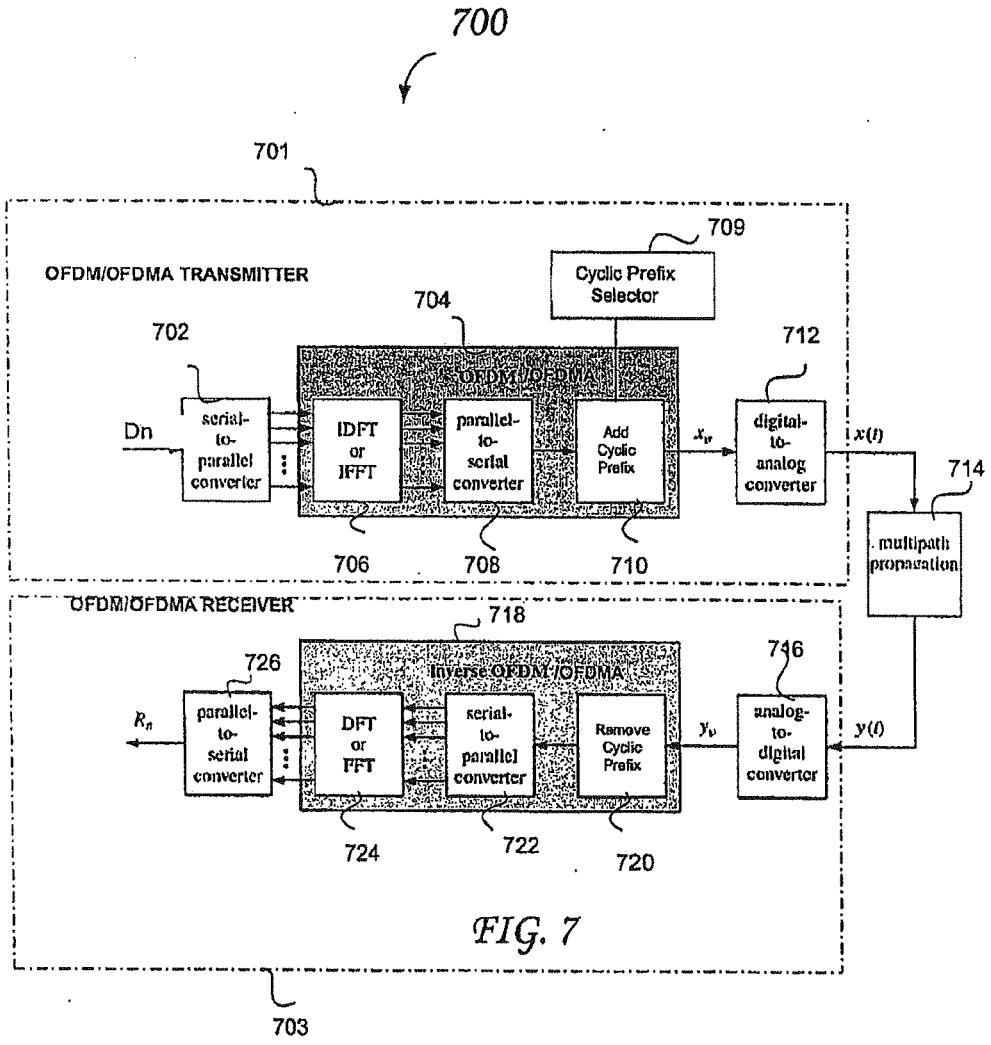
700
701
OFDM/OFDMA TRANSMITTER
709
Cyclic Prefix Selector
704
702
712
OFDM/OFDMA
Dn
serial-to-parallel converter
IDFT or IFFT
parallel-to-serial converter
Add Cyclic Prefix
x_v
digital-to-analog converter
$x(t)$
714
multipath propagation
706
708
710
OFDM/OFDMA RECEIVER
718
726
Inverse OFDM/OFDMA
716
R_n
parallel-to-serial converter
DFT or FFT
serial-to-parallel converter
Remove Cyclic Prefix
y_v
analog-to-digital converter
$y(t)$
724
722
720
703

FIG. 7

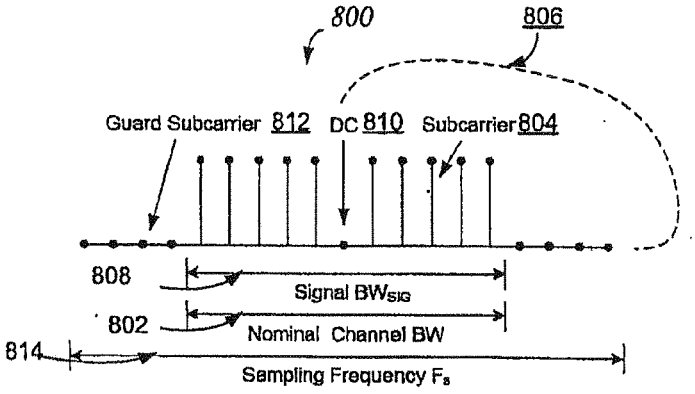
800
806
Guard Subcarrier 812
DC 810
Subcarrier 804
808
Signal BWSIG
802
Nominal Channel BW
814
Sampling Frequency Fs

FIG. 8

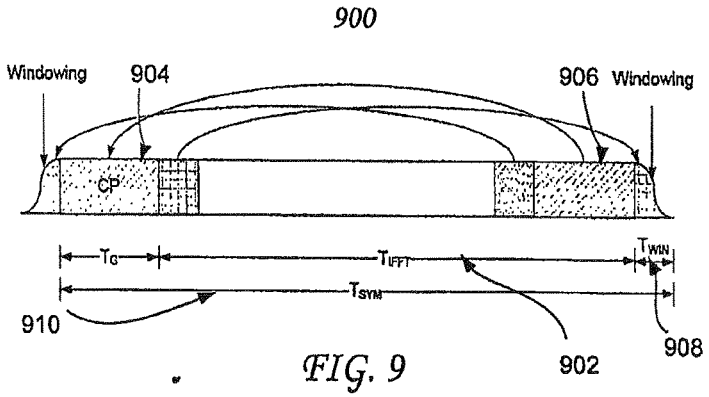
900
Windowing
904
906
Windowing
CP
TG
TIFFT
TWIN
TSYM
910
902
908

FIG. 9

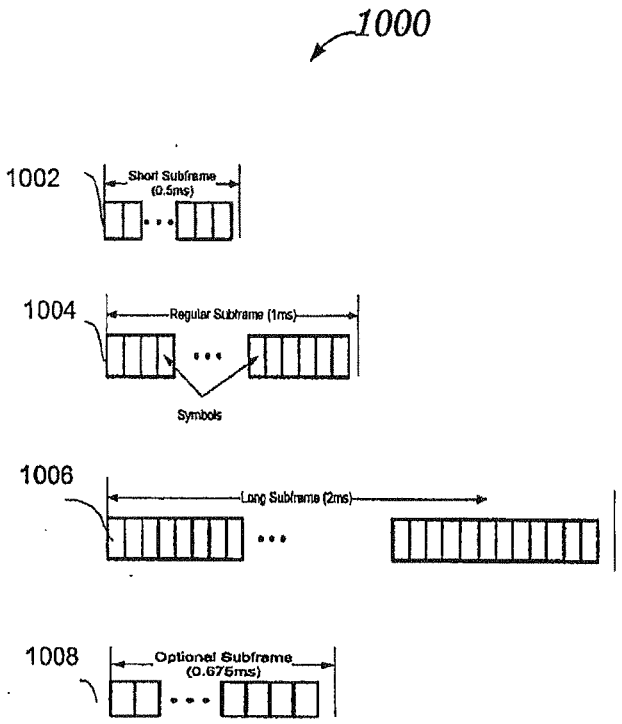
1000
1002
Short Subframe (0.5ms)
1004
Regular Subframe (1ms)
Symbols
1006
Long Subframe (2ms)
1008
Optional Subframe (0.675ms)

FIG. 10

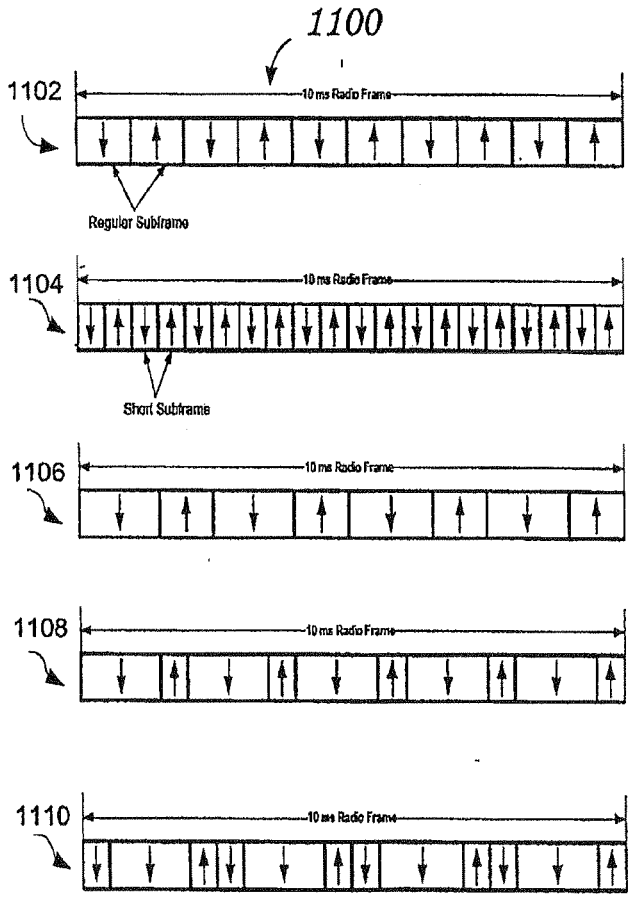
1100
1102
10 ms Radio Frame
Regular Subframe
1104
10 ms Radio Frame
Short Subframe
1106
10 ms Radio Frame
1108
10 ms Radio Frame
1110
10 ms Radio Frame

FIG. 11

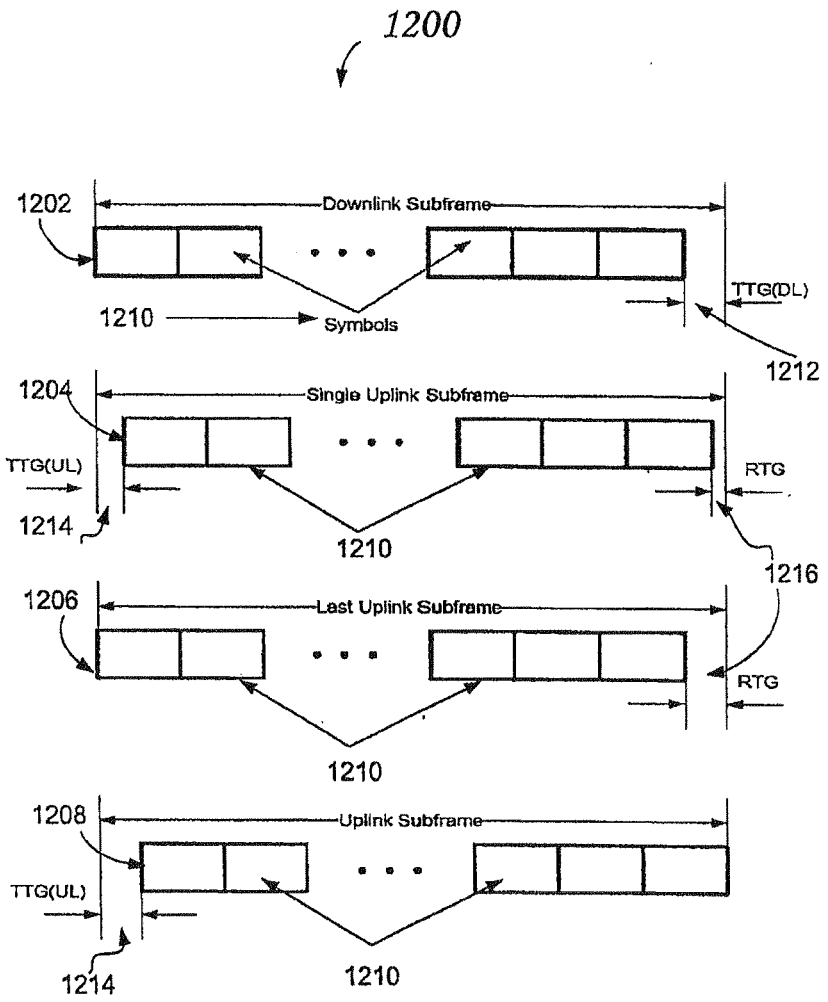
1200
1202
Downlink Subframe
TTG(DL)
1210
Symbols
1212
1204
Single Uplink Subframe
TTG(UL)
RTG
1214
1210
1216
1206
Last Uplink Subframe
RTG
1210
1208
Uplink Subframe
TTG(UL)
1214
1210

FIG. 12

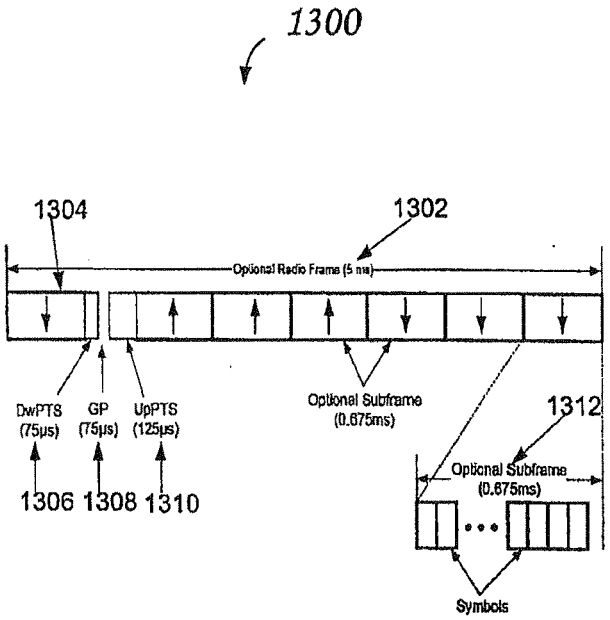
1300
1304
1302
Optional Radio Frame (5 ms)
DwPTS (75μs)
GP (75μs)
UpPTS (125μs)
Optional Subframe (0.675ms)
1312
Optional Subframe (0.675ms)
1306
1308
1310
Symbols

FIG. 13

1400

Parameter		Unit	Parameter Values					
Transmission BW		MHz	1.25	2.5	5	10	20	40
Sub-frame duration (Short)		ms	0.5					
Sub-frame duration (Reg)			1					
Sub-frame duration (Long)			1.5					
Sub-carrier spacing		KHz	12.5					
Sampling frequency		Mhz	1.6	3.2	6.4	12.8	25.6	51.2
FFT size			128	256	512	1024	2048	4096
Number of occupied subcarriers			100	200	400	800	1600	3200
Number of OFDM symbols per sub frame (Short)	Short CP		6					
	Long CP		5					
Number of OFDM symbols per sub frame (Reg)	Short CP		12					
	Normal CP		11					
	Long CP		10					
Number of OFDM symbols per sub frame (Long)	Short CP		18					
	Normal CP		16					
	Long CP		15					
TG + Twin	Short	µs	3.125	3.125	3.125	3.125	3.125	3.125
		samples	5	10	20	40	80	160
	Normal	µs	10	10	10	10	10	10
		samples	16	32	64	128	256	512
	Long	µs	16.875	16.875	16.875	16.875	16.875	16.875
		samples	27	54	108	216	432	864
DL-TTG, UL-TTG, UL-RTG of sub frame (Short)	Short CP	µs	1.25		1.25		0	
	Long CP		15.625		14.375		1.25	
DL-TTG, UL-TTG, UL-RTG of sub frame (Reg)	Short CP	µs	2.5		2.5		0	
	Normal CP		10		8.75		1.25	
	Long CP		31.25		30		1.25	
DL-TTG, UL-TTG, UL-RTG of sub frame (Long)	Short CP	µs	3.75		2.5		1.25	
	Normal CP		60		58.75		1.25	
	Long CP		46.875		45.625		1.25	

FIG. 14

1500

Parameter		Unit	Parameter Values					
Transmission BW		MHz	3.5	7	14	28	56	112
Sub-frame duration (Short)		ms	0.5					
Sub-frame duration (Reg)			1					
Sub-frame duration (Long)			1.5					
Sub-carrier Spacing (Δf)		KHz	12.5					
Sampling frequency		Mhz	6.4	12.8	25.6	51.2	102.4	204.8
FFT size			512	1024	2048	4096	8192	16384
Number of occupied subcarriers			280	560	1120	2240	4480	8960
Number of OFDM symbols per sub frame (Short)	Short CP		6					
	Long CP		5					
Number of OFDM symbols per sub frame (Reg)	Short CP		12					
	Normal CP		11					
	Long CP		10					
Number of OFDM symbols per sub frame (Long)	Short CP		18					
	Normal CP		16					
	Long CP		15					
TG + Twin	Short	μs	2.96875	3.28125	3.28125	3.28125	3.28125	3.28125
		samples	19	42	84	168	336	672
	Normal	μs	10	10	10	10	10	10
		samples	64	128	256	512	1024	2048
	Long	μs	16.71875	16.71875	16.71875	16.71875	16.71875	16.71875
		samples	107	214	428	856	1712	3424
DL-TTG, UL-TTG, UL-RTG of sub frame (Short)	Short CP	μs	2.1875		2.1875		0	
	Long CP		16.40625		16.09375		0.3125	
DL-TTG, UL-TTG, UL-RTG of sub frame (Reg)	Short CP	μs	4.375		4.375		0	
	Normal CP		10		9.6875		0.3125	
	Long CP		32.8125		32.5		0.3125	
DL-TTG, UL-TTG, UL-RTG of sub frame (Long)	Short CP	μs	6.5625		6.25		0.3125	
	Normal CP		60		59.6875		0.3125	
	Long CP		49.21875		48.90625		0.3125	

FIG. 15

1600

Parameter		Unit	Parameter Values					
Transmission BW		MHz	1.25	2.5	5	10	20	40
Sub-carrier Spacing (Δf)		KHz	12.5					
Sampling frequency		Mhz	1.6	3.2	6.4	12.8	25.6	51.2
FFT size			128	256	512	1024	2048	4096
Number of occupied subcarriers			101	201	401	801	1601	3201
TG + Twin	Short CP	μs	2.5	2.5	2.5	2.5	2.5	2.5
		samples	4	8	16	32	64	128
	Normal CP	μs	9.375	9.375	9.375	9.375	9.375	9.375
		samples	15	30	60	120	240	480
	Long CP	μs	16.875	16.875	16.875	16.875	16.875	16.875
		samples	27	54	108	216	432	864

FIG. 16

1700

Parameter		Unit	Parameter Values					
Transmission BW		MHz	3.5	7	14	28	56	112
Sub-carrier Spacing (Δf)		KHz	12.5					
Sampling Frequency (Fs)		Mhz	6.4	12.8	25.6	51.2	102.4	204.8
FFT size			512	1024	2048	4096	8192	16384
Number of occupied subcarriers			280	560	1120	2240	4480	8960
TG + Twin	Short CP	μs	2.5	2.5	2.5	2.5	2.5	2.5
		samples	16	32	64	128	256	512
	Normal CP	μs	9.375	9.375	9.375	9.375	9.375	9.375
		samples	60	120	240	480	960	1920
	Long CP	μs	16.875	16.875	16.875	16.875	16.875	16.875
		samples	108	216	432	864	1728	3456

FIG. 17

1800

0.5 (ms) Sub-frame duration		ms	0.5		
Number of OFDM symbols per sub frame	Short CP (N_S)		6		
	Normal CP (N_R)		5		
	Long CP (N_L)		4		
Total Idle Time	Short CP	μs	5		
	Normal CP		53.125		
	Long CP		112.5		
TTG-DL, TTG-UL, RTG-UL of sub frame (TTG = TTG-DL+TTG-UL, RTG = RTG-UL)	Short CP	μs	5	2.5	2.5
	Normal CP		53.125	50.625	2.5
	Long CP		112.5	110	2.5

FIG. 18

1900

0.675 (ms) Sub-frame duration		ms	0.675		
Number of OFDM symbols per sub frame	Short CP (N_S)		8		
	Normal CP (N_R)		7		
	Long CP (N_L)		6		
Total Idle Time	Short CP	μs	15		
	Normal CP		49.375		
	Long CP		93.75		
TTG-DL, TTG-UL, RTG-UL of sub frame (TTG = TTG-DL+TTG-UL, RTG = RTG-UL)	Short CP	μs	15	12.5	2.5
	Normal CP		49.375	46.875	2.5
	Long CP		93.75	91.25	2.5

FIG. 19

2000

1.0 (ms) Sub-frame duration		ms	1		
Number of OFDM symbols per sub frame	Short CP (N_S)		12		
	Normal CP (N_R)		11		
	Long CP (N_L)		10		
Total Idle Time	Short CP	μs	10		
	Normal CP		16.875		
	Long CP		31.25		
TTG-DL, TTG-UL, RTG UL of sub frame (TTG = TTG-DL+TTG-UL, RTG = RTG-UL)	Short CP	μs	10	7.5	2.5
	Normal CP		16.875	14.375	2.5
	Long CP		31.25	28.75	2.5

FIG. 20

2100

1.5 (ms) Sub-frame duration		ms	1.5		
Number of OFDM symbols per sub frame	Short CP (N_S)		18		
	Normal CP (N_R)		16		
	Long CP (N_L)		15		
Total Idle Time	Short CP	μs	15		
	Normal CP		70		
	Long CP		46.875		
TTG-DL, TTG-UL, RTG UL of sub frame (TTG = TTG-DL+TTG-UL, RTG = RTG-UL)	Short CP	μs	15	12.5	2.5
	Normal CP		70	67.5	2.5
	Long CP		46.875	44.375	2.5

FIG. 21

2200

2.0 (ms) Sub-frame duration		ms	2		
Number of OFDM symbols per sub frame	Short CP (N_S)		24		
	Normal CP (N_N)		22		
	Long CP (N_L)		20		
Total Idle Time	Short CP	μs	20		
	Normal CP		33.75		
	Long CP		62.5		
TTG-DL, TTG-UL, RTG UL of sub frame (TTG = TTG-DL+TTG-UL, RTG = RTG-UL)	Short CP	μs	20	17.5	2.5
	Normal CP		33.75	31.25	2.5
	Long CP		82.5	80	2.5

FIG. 22

2300

2.5 (ms) Sub-frame duration		ms	2.5		
Number of OFDM symbols per sub frame	Short CP (N_S)		30		
	Normal CP (N_N)		27		
	Long CP (N_L)		25		
Total Idle Time	Short CP	μs	25		
	Normal CP		86.875		
	Long CP		78.125		
TTG-DL, TTG-UL, RTG UL of sub frame (TTG = TTG-DL+TTG-UL, RTG = RTG-UL)	Short CP	μs	25	22.5	2.5
	Normal CP		86.875	84.375	2.5
	Long CP		78.125	75.625	2.5

FIG. 23

2400

Parameter		Unit	Parameter Values					
Transmissin Bandwidth (BW)		MHz	5	7	8.75	10	14	20
Sub-carrier Spacing (Δf)		KHz	10.9375					
Sampling Frequency (Fs)		Mhz	5.6	11.2	11.2	11.2	22.4	22.4
FFT size			512	1024	1024	1024	2048	2048
Number of Used sub-carriers			TBD	TBD	TBD	TBD	TBD	TBD
CP Length (T_G)	Short CP	µs	2.85714286	2.857143	2.857143	2.857143	2.857143	2.857143
	Normal CP	µs	11.4285714	11.42857	11.42857	11.42857	11.42857	11.42857
	Long CP	µs	17.1428571	17.14286	17.14286	17.14286	17.14286	17.14286
	Long CP 2	µs	22.8571429	22.85714	22.85714	22.85714	22.85714	22.85714
Sub-frame duration		ms	0.5	0.675	1	1.5	2	2.5
Number of OFDM Symbols Per Sub-frame	Short CP (N_S)		5	7	10	15	21	26
	Normal CP (N_R)		4	6	9	14	19	24
	Long CP (N_L)		4	5	8	13	18	22
	Long CP 2 (N_L)		3	5	8	12	17	21
Sub-Frame Idle Time (TTG-DL or TTG-UL)	Short CP	µs	28.5714286	15	57.14286	85.71429	20	48.57143
	Normal CP		88.5714286	57.85714	74.28571	60	45.71429	31.42857
	Long CP		65.7142857	132.1429	131.4286	88.57143	45.71429	111.4286
	Long CP 2		157.142857	103.5714	85.71429	128.5714	57.14286	100

FIG. 24

2500

Parameter		Unit	Parameter Values					
TRansmission Bandwidth (BW)		MHz	5	7	8.75	10	14	20
Sub-carrier Spacing (Δf)		KHz	12.5					
Sampling Frequency (Fs)		Mhz	6.4	12.8	12.8	12.8	25.6	25.6
FFT size			512	1024	1024	1024	2048	2048
Number of Used sub-carriers			401	561	701	801	1121	1601
CP Length (T_G)	Short CP	µs	2.5	2.5	2.5	2.5	2.5	2.5
	Normal CP	µs	10	10	10	10	10	10
	Long CP	µs	15	15	15	15	15	15
	Long CP 2	µs	20	20	20	20	20	20
Sub-frame duration		ms	0.5	0.675	1	1.5	2	2.5
Number of OFDM Symbols Per Sub-frame	Short CP (N_S)		6	8	12	18	24	30
	Normal CP (N_R)		5	7	10	16	22	27
	Long CP (N_L)		4	6	10	15	20	26
	Long CP 2 (N_L)		4	6	9	14	19	24
Sub-Frame Idle Time (TTG-DL or TTG-UL)	Short CP	µs	5	15	10	15	20	25
	Normal CP		50	45	100	60	20	70
	Long CP		120	105	50	75	100	30
	Long CP 2		100	75	100	100	100	100

FIG. 25

2600

Parameter		Unit	Parameter Values					
Transmission Bandwidth (BW)		MHz	5	7	8.75	10	14	20
Sub-carrier Spacing (Δf)		KHz	25					
Sampling Frequency (Fs)		Mhz	6.4	12.8	12.8	12.8	25.6	25.6
FFT size			256	512	512	512	1024	1024
Number of Used sub-carriers			201	281	351	401	561	801
CP Length (T_G)	Short CP	µs	2.5	2.5	2.5	2.5	2.5	2.5
	Normal CP	µs	10	10	10	10	10	10
	Long CP	µs	15	15	15	15	15	15
	Long CP 2	µs	20	20	20	20	20	20
Sub-frame duration		ms	0.5	0.675	1	1.5	2	2.5
Number of OFDM Symbols Per Sub-frame	Short CP (N_S)		11	15	23	35	46	58
	Normal CP (N_R)		9	13	19	29	39	49
	Long CP (N_L)		8	11	17	26	35	44
	Long CP 2 (N_L)		7	10	16	24	32	41
Sub-Frame Idle Time (TTG-DL or TTG-UL)	Short CP	µs	32.5	37.5	22.5	12.5	45	35
	Normal CP		50	25	50	50	50	50
	Long CP		60	70	65	70	75	80
	Long CP 2		80	75	40	60	80	40

FIG. 26

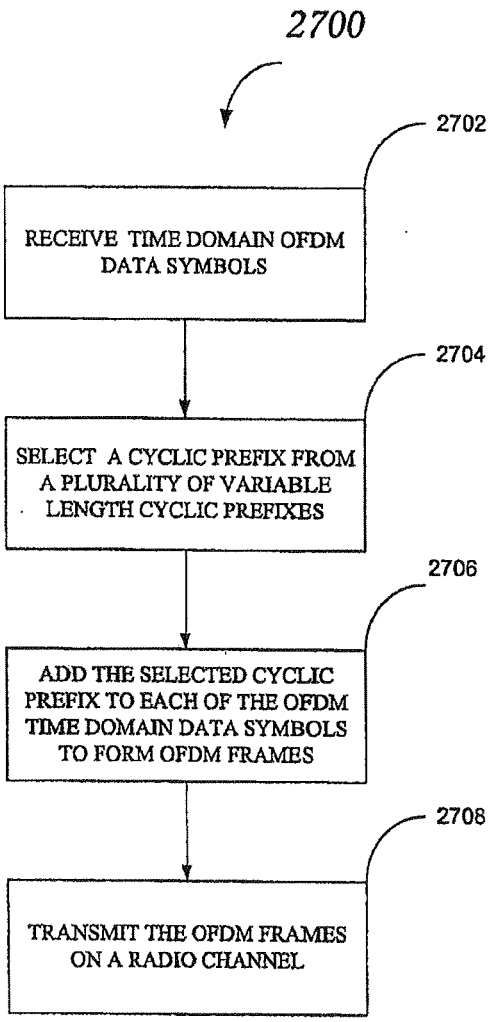
2700
2702
RECEIVE TIME DOMAIN OFDM DATA SYMBOLS
2704
SELECT A CYCLIC PREFIX FROM A PLURALITY OF VARIABLE LENGTH CYCLIC PREFIXES
2706
ADD THE SELECTED CYCLIC PREFIX TO EACH OF THE OFDM TIME DOMAIN DATA SYMBOLS TO FORM OFDM FRAMES
2708
TRANSMIT THE OFDM FRAMES ON A RADIO CHANNEL

FIG. 27