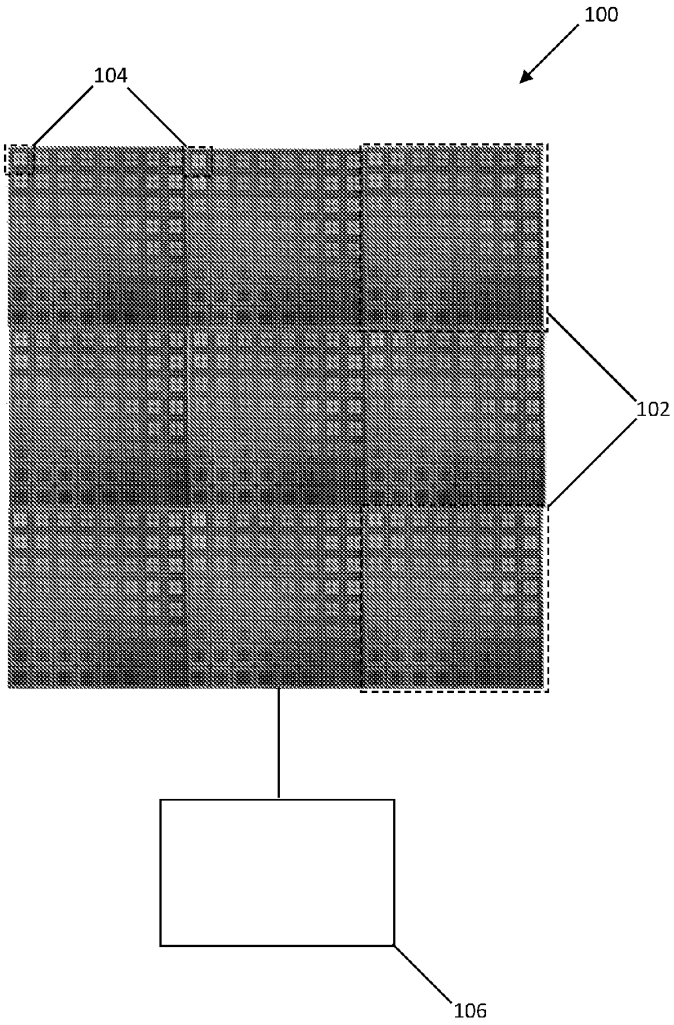


FIG. 1

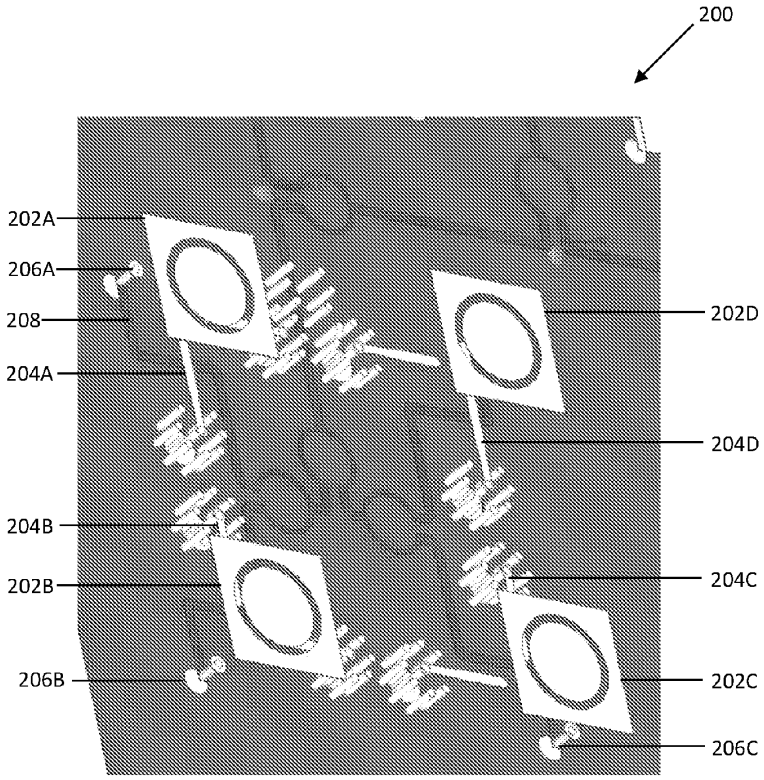

200
202A
206A
208
204A
202D
204D
204B
202B
204C
206B
202C
206C

FIG. 2

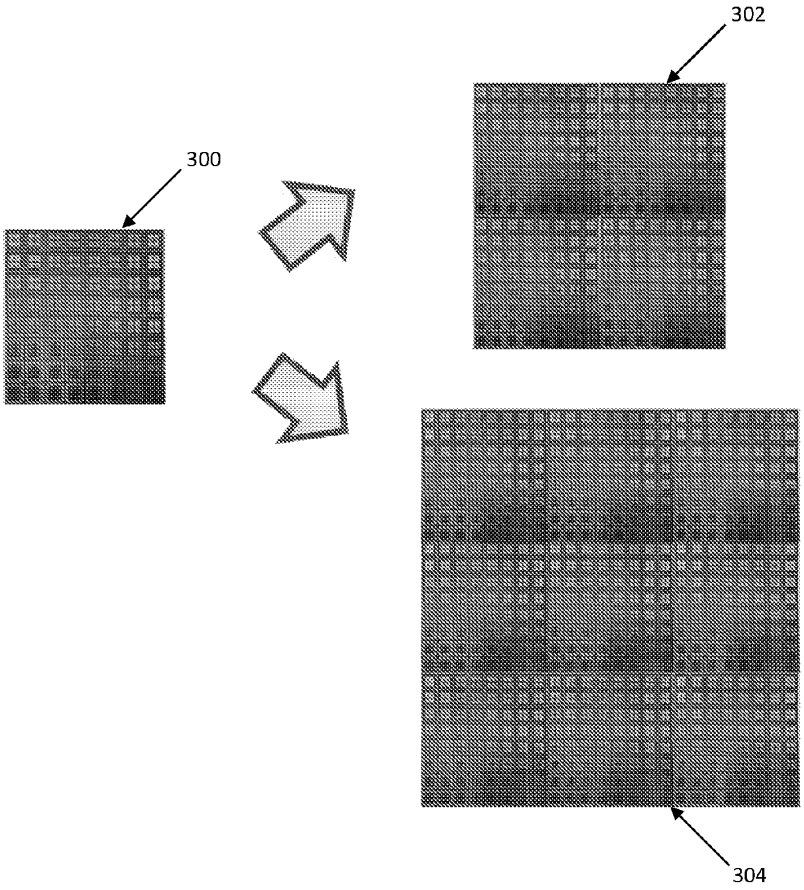


FIG. 3

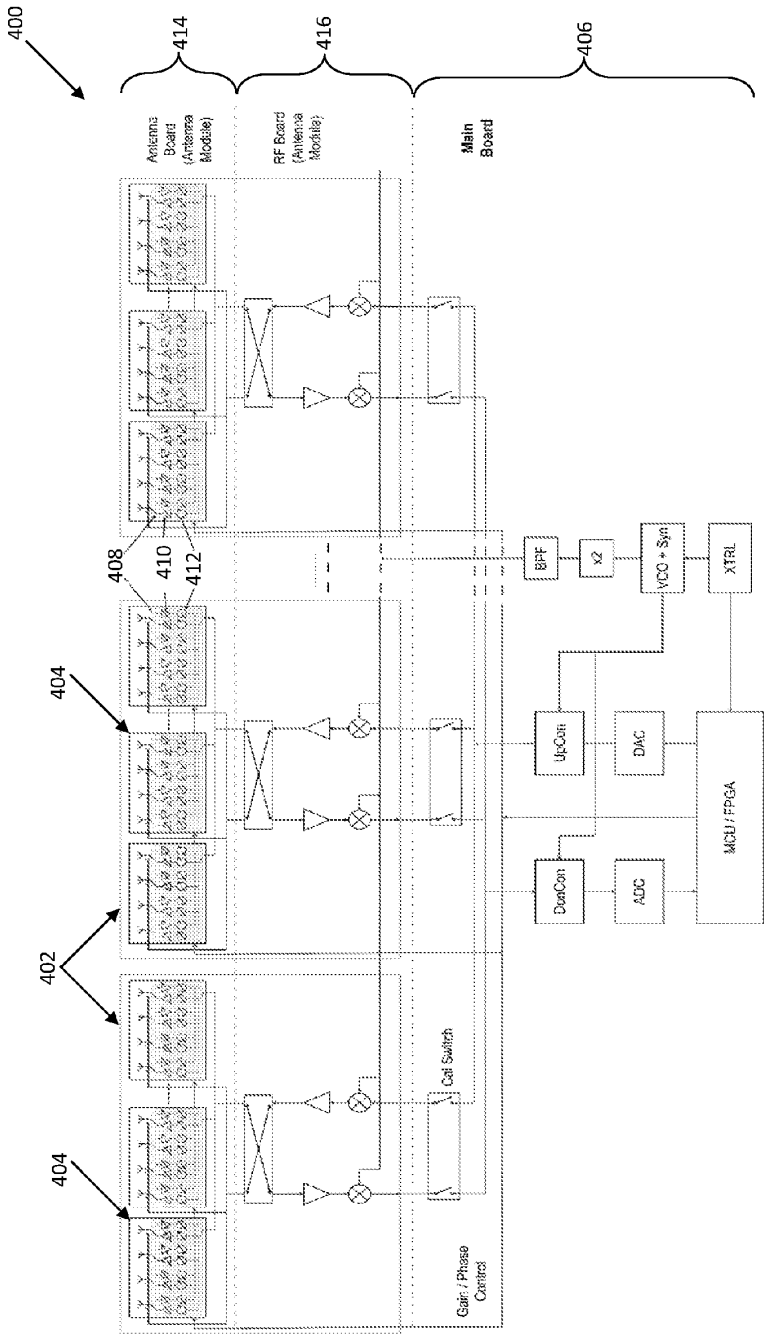

400
414
416
406
Antenna Board (Antenna Module)
RF Board (Antenna Module)
Main Board
408
410
412
404
402
404
BPF
x2
VCO + Syn
XTRL
UpCon
DAC
MCU / FPGA
DonCon
ADC
Cal Switch
Gain / Phase Control

FIG. 4A

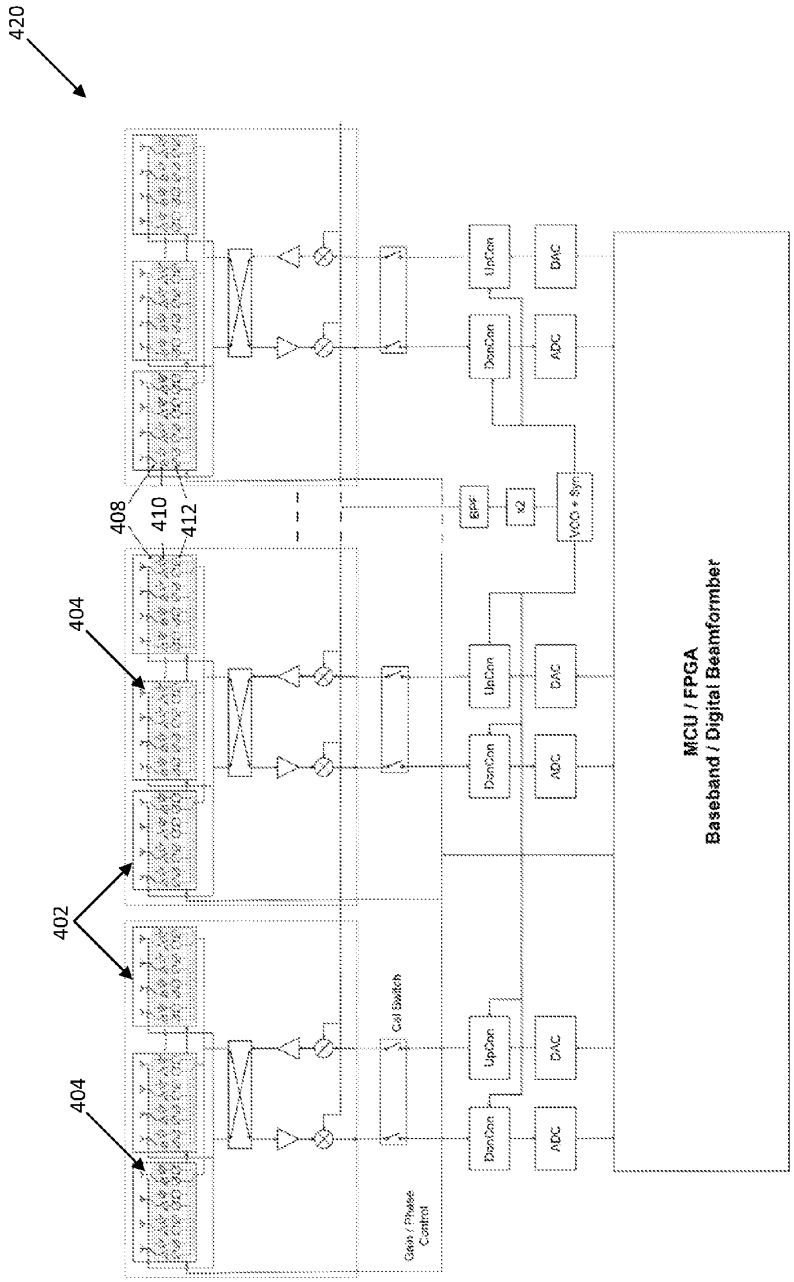

420
408
410
412
404
402
404
Gain / Phase Control
Cal Switch
UpCon
DownCon
DAC
ADC
BPF
x2
VCO + Syn
MCU / FPGA
Baseband / Digital Beamformer

FIG. 4B

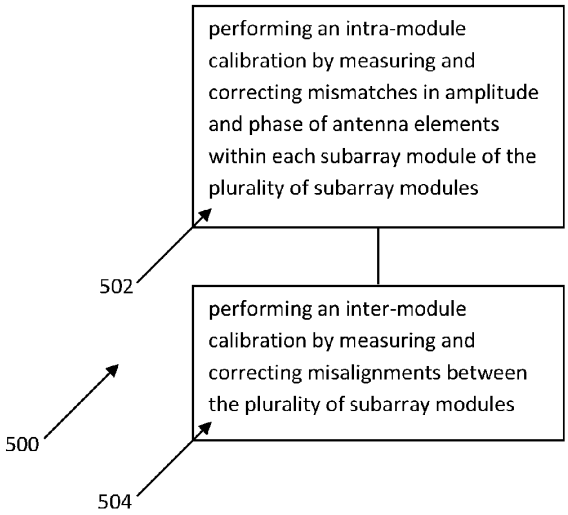

performing an intra-module calibration by measuring and correcting mismatches in amplitude and phase of antenna elements within each subarray module of the plurality of subarray modules
502
performing an inter-module calibration by measuring and correcting misalignments between the plurality of subarray modules
500
504

FIG. 5

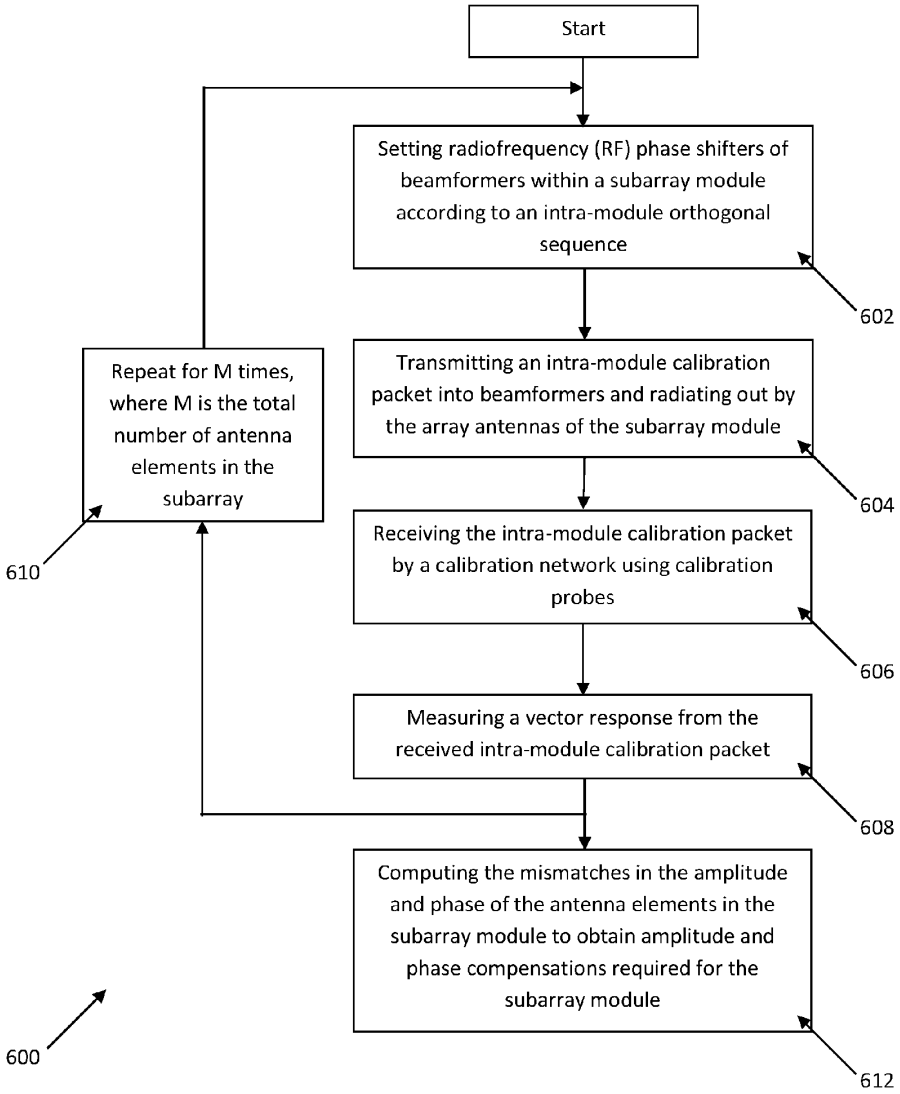

Start
Setting radiofrequency (RF) phase shifters of beamformers within a subarray module according to an intra-module orthogonal sequence
602
Transmitting an intra-module calibration packet into beamformers and radiating out by the array antennas of the subarray module
604
Receiving the intra-module calibration packet by a calibration network using calibration probes
606
Measuring a vector response from the received intra-module calibration packet
608
Computing the mismatches in the amplitude and phase of the antenna elements in the subarray module to obtain amplitude and phase compensations required for the subarray module
612
Repeat for M times, where M is the total number of antenna elements in the subarray
610
600

FIG. 6

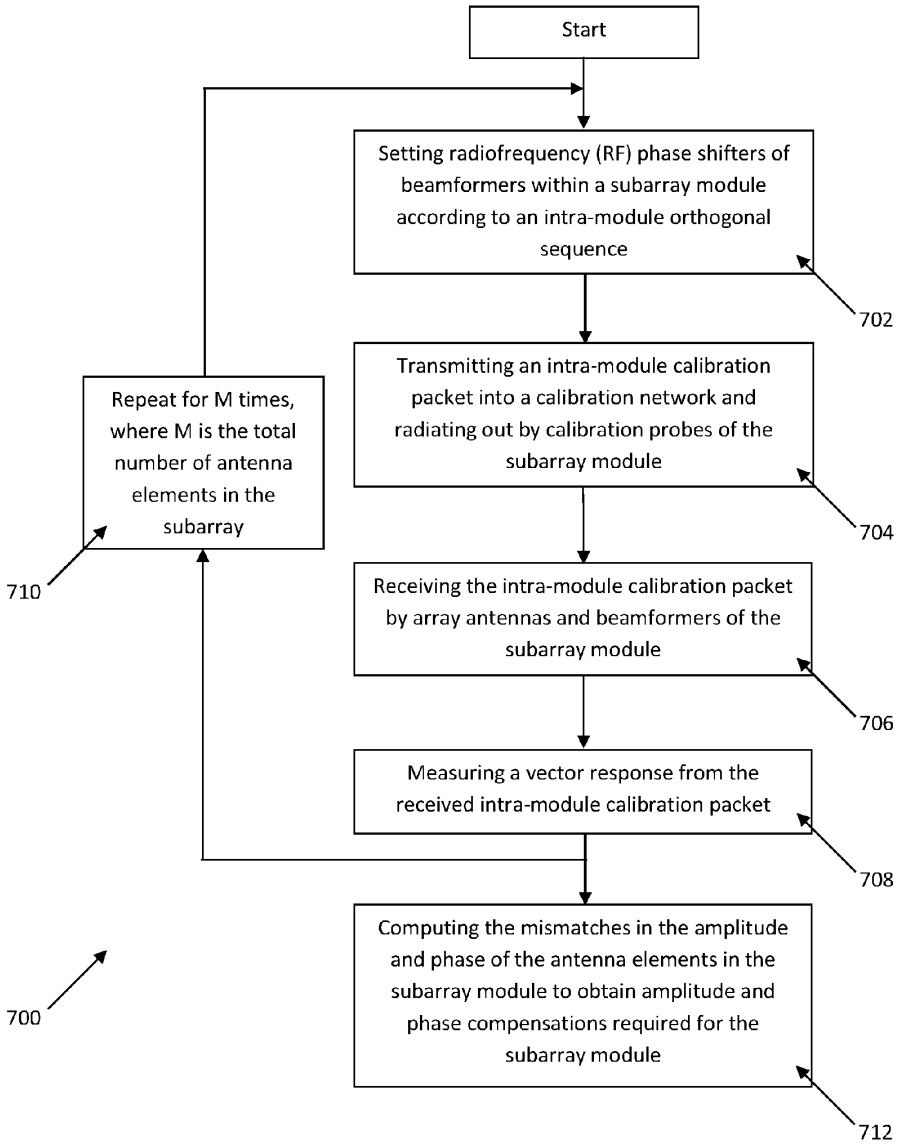

Start
Setting radiofrequency (RF) phase shifters of beamformers within a subarray module according to an intra-module orthogonal sequence
702
Transmitting an intra-module calibration packet into a calibration network and radiating out by calibration probes of the subarray module
704
Receiving the intra-module calibration packet by array antennas and beamformers of the subarray module
706
Measuring a vector response from the received intra-module calibration packet
708
Computing the mismatches in the amplitude and phase of the antenna elements in the subarray module to obtain amplitude and phase compensations required for the subarray module
712
Repeat for M times, where M is the total number of antenna elements in the subarray
710
700

FIG. 7

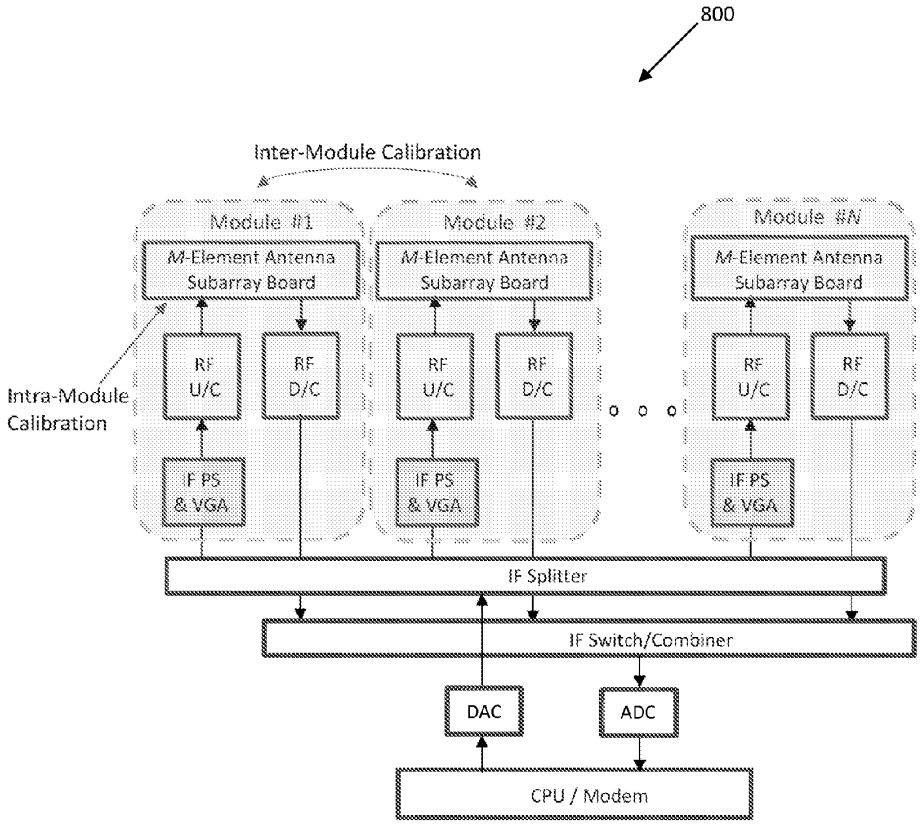

800
Inter-Module Calibration
Module #1
Module #2
Module #N
M-Element Antenna Subarray Board
M-Element Antenna Subarray Board
M-Element Antenna Subarray Board
Intra-Module Calibration
RF U/C
RF D/C
RF U/C
RF D/C
RF U/C
RF D/C
IF PS & VGA
IF PS & VGA
IF PS & VGA
IF Splitter
IF Switch/Combiner
DAC
ADC
CPU / Modem

FIG. 8A

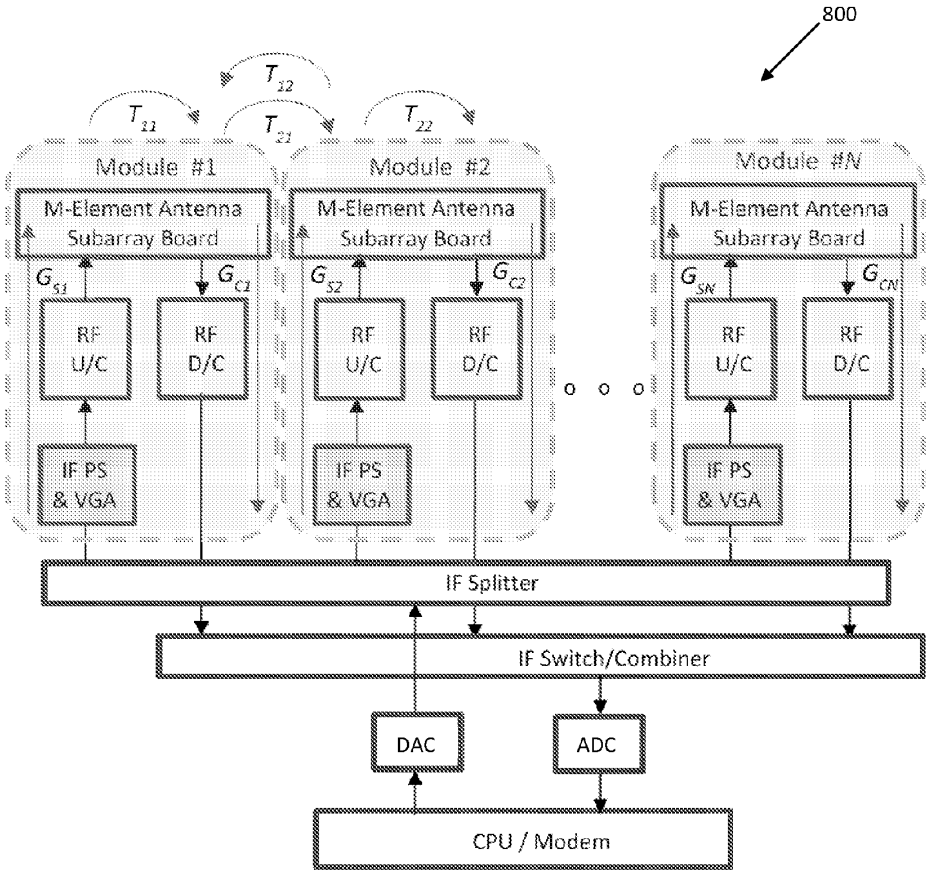

800
T_{12}
T_{11}
T_{21}
T_{22}
Module #1
Module #2
Module #N
M-Element Antenna Subarray Board
M-Element Antenna Subarray Board
M-Element Antenna Subarray Board
G_{S1}
G_{C1}
G_{S2}
G_{C2}
G_{SN}
G_{CN}
RF U/C
RF D/C
RF U/C
RF D/C
RF U/C
RF D/C
IF PS & VGA
IF PS & VGA
IF PS & VGA
IF Splitter
IF Switch/Combiner
DAC
ADC
CPU / Modem

FIG. 8B

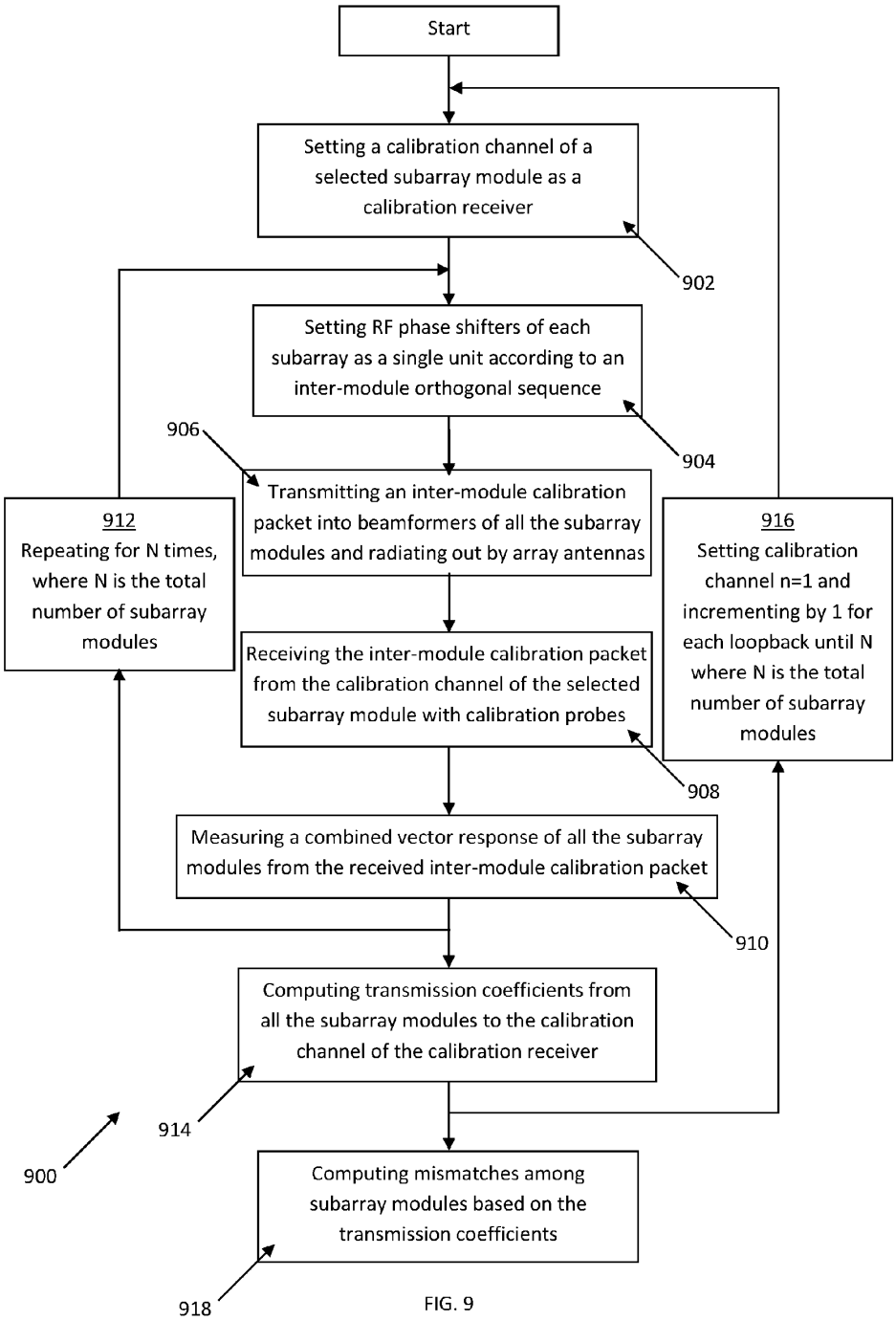

Start
Setting a calibration channel of a selected subarray module as a calibration receiver
902
Setting RF phase shifters of each subarray as a single unit according to an inter-module orthogonal sequence
904
906
Transmitting an inter-module calibration packet into beamformers of all the subarray modules and radiating out by array antennas
912
Repeating for N times, where N is the total number of subarray modules
916
Setting calibration channel n=1 and incrementing by 1 for each loopback until N where N is the total number of subarray modules
Receiving the inter-module calibration packet from the calibration channel of the selected subarray module with calibration probes
908
Measuring a combined vector response of all the subarray modules from the received inter-module calibration packet
910
Computing transmission coefficients from all the subarray modules to the calibration channel of the calibration receiver
914
900
Computing mismatches among subarray modules based on the transmission coefficients
918

FIG. 9

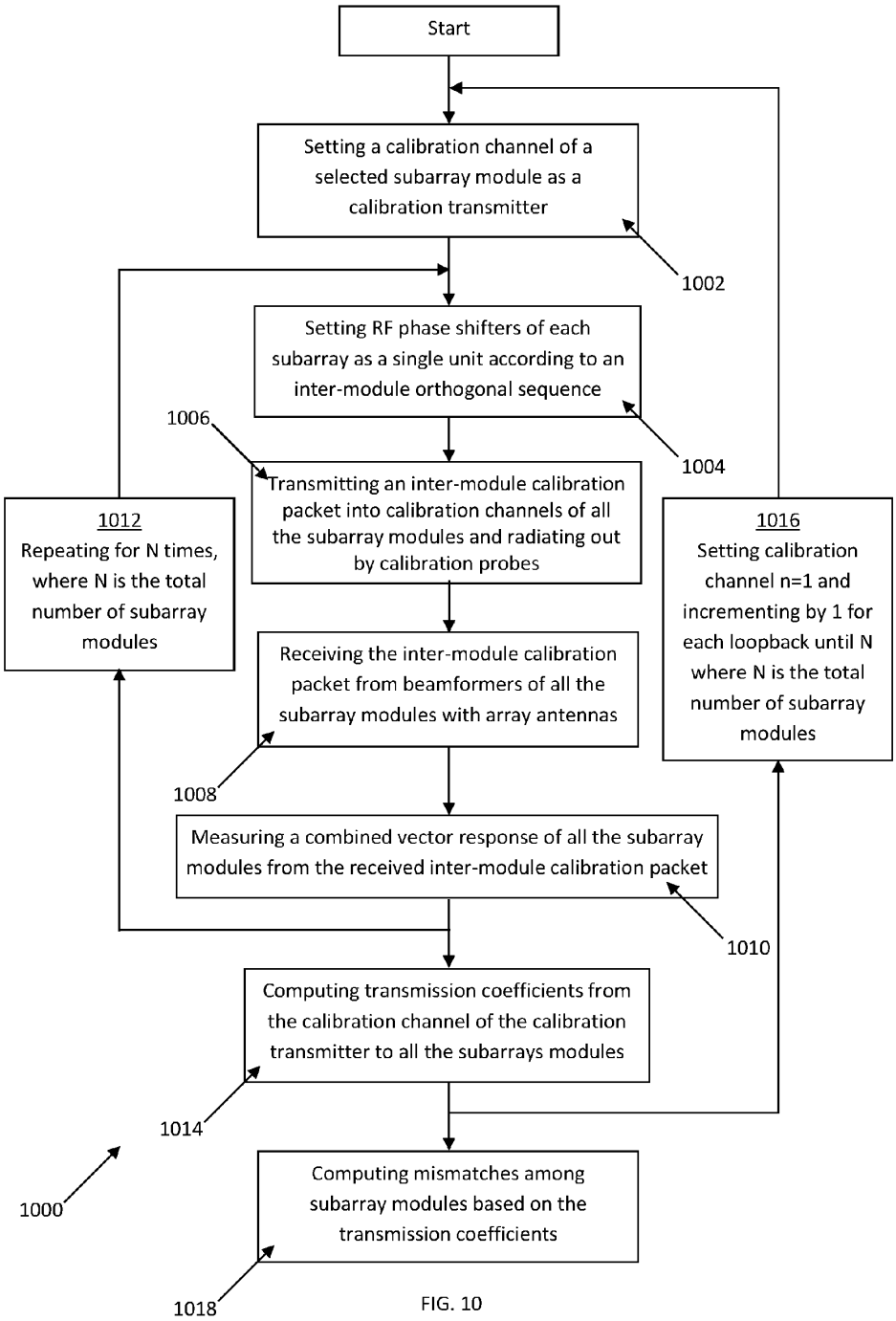

Start
Setting a calibration channel of a selected subarray module as a calibration transmitter
1002
Setting RF phase shifters of each subarray as a single unit according to an inter-module orthogonal sequence
1004
1006
Transmitting an inter-module calibration packet into calibration channels of all the subarray modules and radiating out by calibration probes
Receiving the inter-module calibration packet from beamformers of all the subarray modules with array antennas
1008
Measuring a combined vector response of all the subarray modules from the received inter-module calibration packet
1010
Computing transmission coefficients from the calibration channel of the calibration transmitter to all the subarrays modules
1014
Computing mismatches among subarray modules based on the transmission coefficients
1018
1000
1012
Repeating for N times, where N is the total number of subarray modules
1016
Setting calibration channel n=1 and incrementing by 1 for each loopback until N where N is the total number of subarray modules

FIG. 10

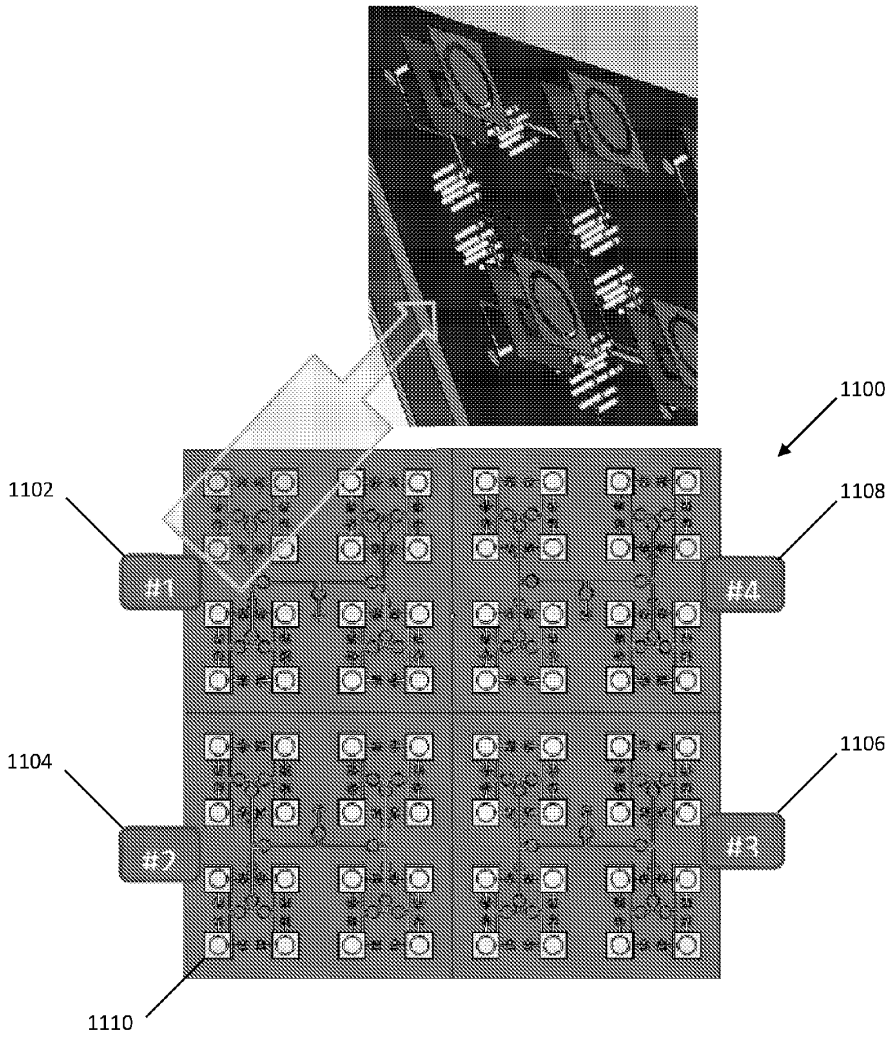


FIG. 11

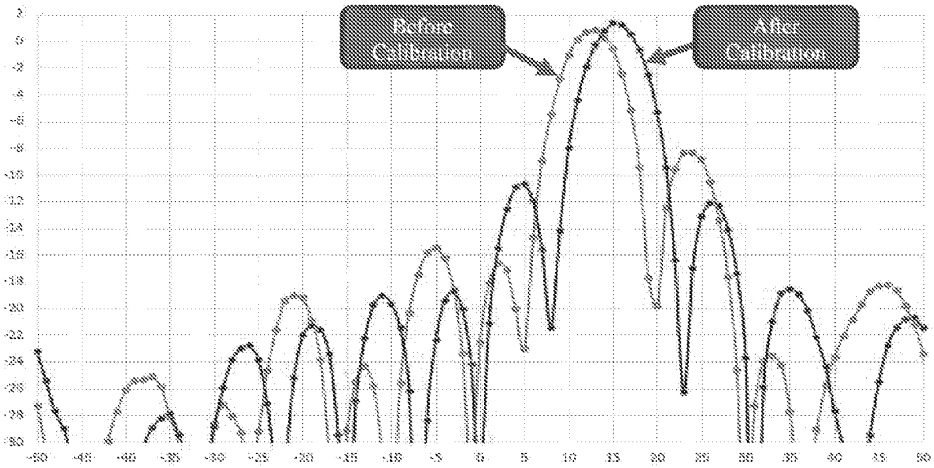


FIG. 12

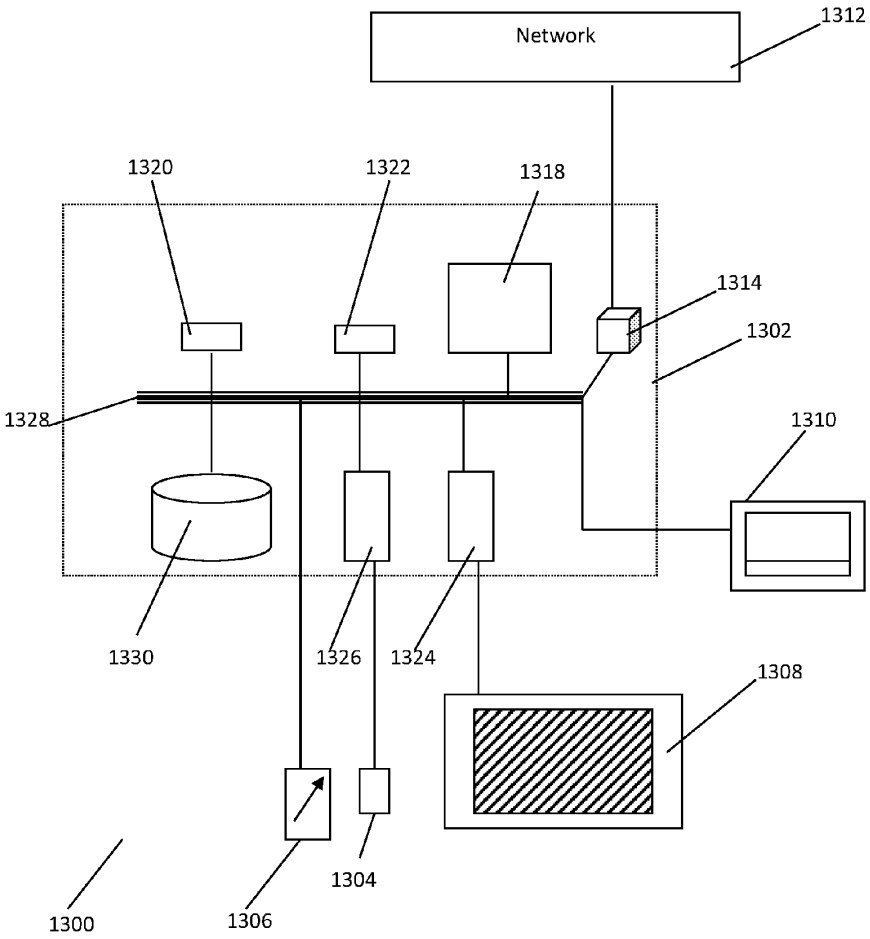

Network
1312
1320
1322
1318
1314
1302
1328
1310
1330
1326
1324
1308
1304
1306
1300

FIG. 13