
Random Data
X(m,n)
ISFFT
X̃(k,l)
Heisenberg Transform
s(t)
Radar Processor
SFFT
Ỹ(k,l)
Wigner Transform
r(t)

FIG. 1

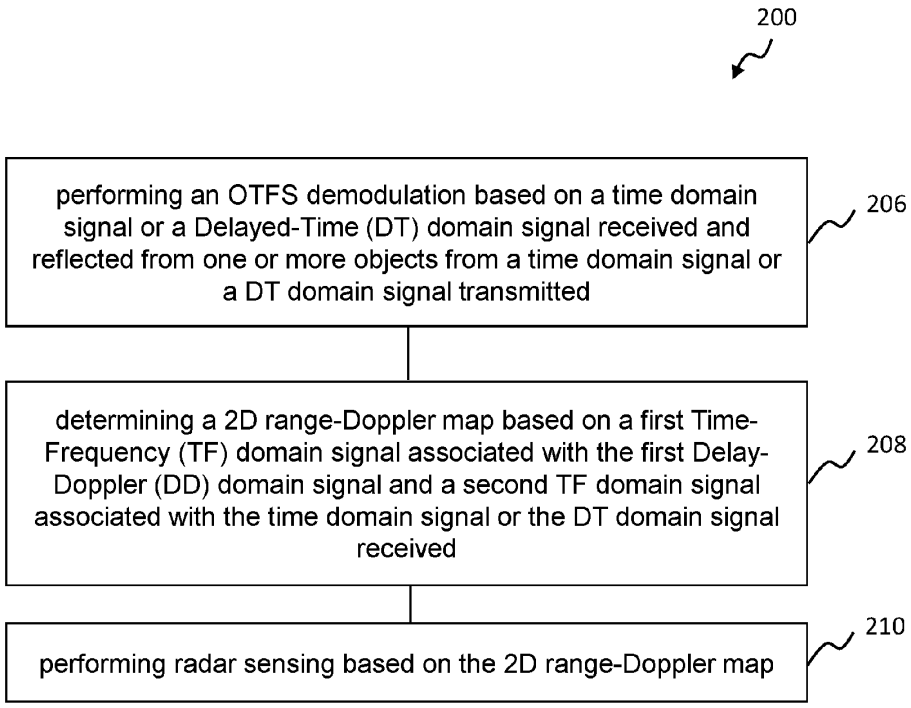
200
performing an OTFS demodulation based on a time domain signal or a Delayed-Time (DT) domain signal received and reflected from one or more objects from a time domain signal or a DT domain signal transmitted
206
determining a 2D range-Doppler map based on a first Time-Frequency (TF) domain signal associated with the first Delay-Doppler (DD) domain signal and a second TF domain signal associated with the time domain signal or the DT domain signal received
208
performing radar sensing based on the 2D range-Doppler map
210

FIG. 2

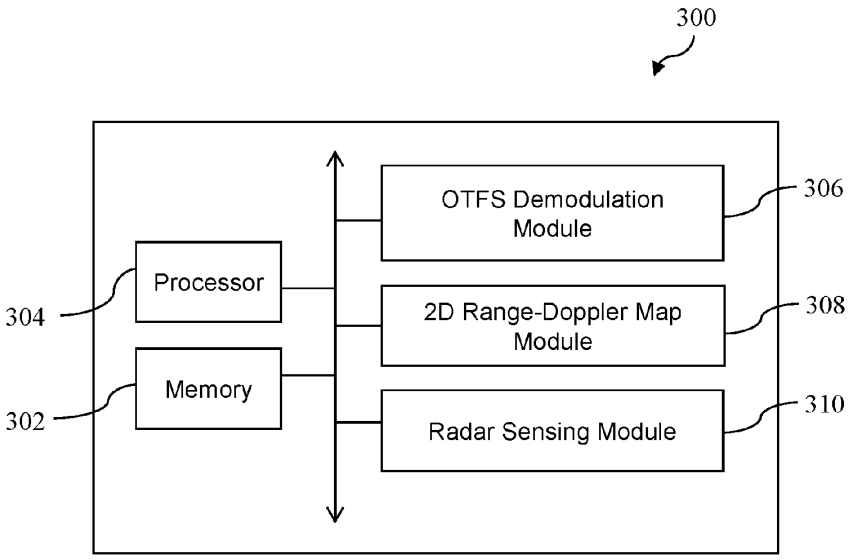
300
OTFS Demodulation Module
306
Processor
304
2D Range-Doppler Map Module
308
Memory
302
Radar Sensing Module
310

FIG. 3

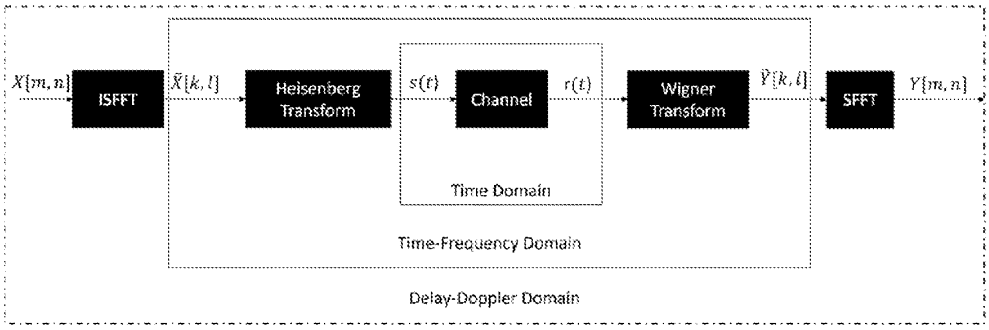
X[m, n]
ISFFT
X̃[k, l]
Heisenberg Transform
s(t)
Channel
r(t)
Wigner Transform
Ỹ[k, l]
SFFT
Y[m, n]
Time Domain
Time-Frequency Domain
Delay-Doppler Domain

FIG. 4

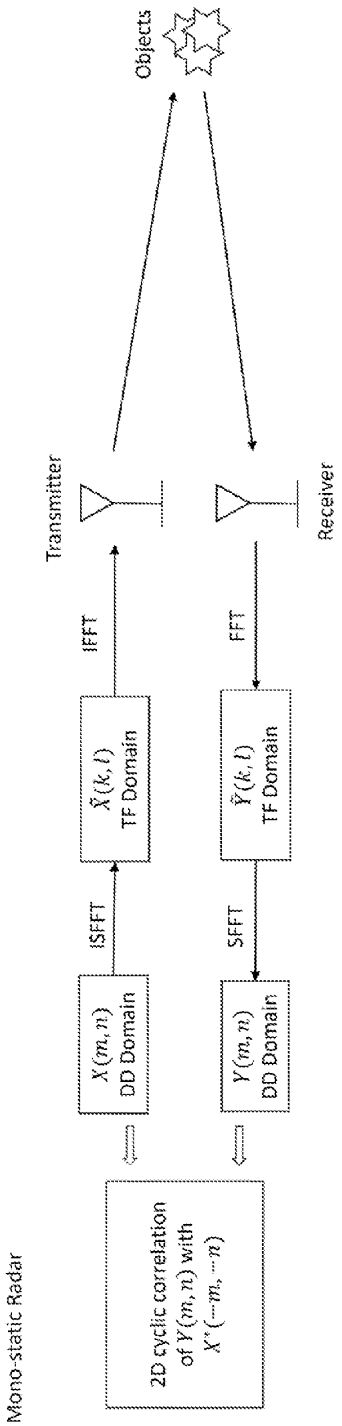
500
Objects
Transmitter
Receiver
IFFT
FFT
$\tilde{X}(k,l)$ TF Domain
$\tilde{Y}(k,l)$ TF Domain
ISFFT
SFFT
$X(m,n)$ DD Domain
$Y(m,n)$ DD Domain
2D cyclic correlation of $Y(m,n)$ with $X^*(-m,-n)$
Mono-static Radar

FIG. 5A

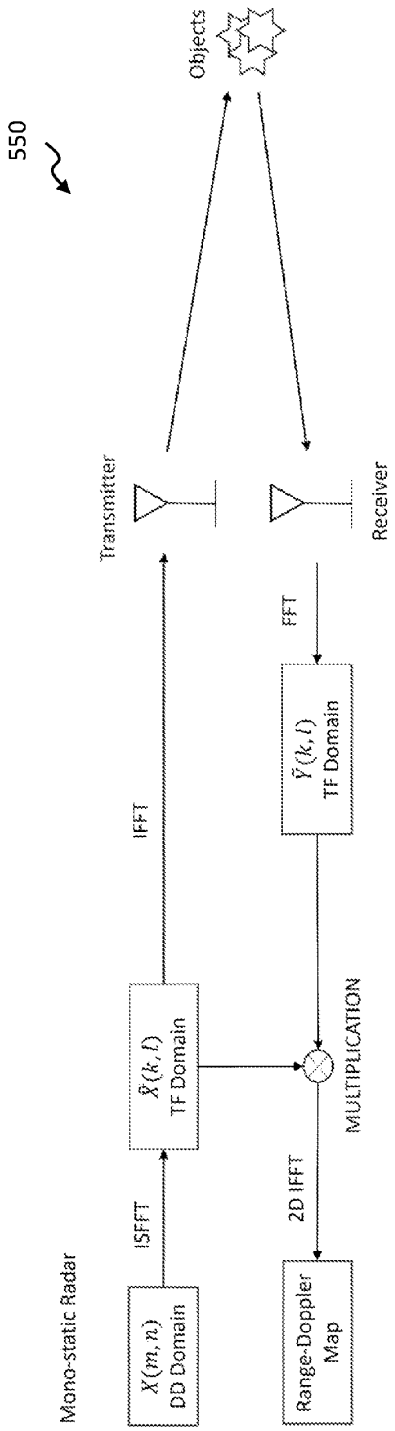
550
Objects
Transmitter
Receiver
IFFT
FFT
$\tilde{X}(k,l)$ TF Domain
$\tilde{Y}(k,l)$ TF Domain
ISFFT
2D IFFT
MULTIPLICATION
$X(m,n)$ DD Domain
Range-Doppler Map
Mono-static Radar

FIG. 5B

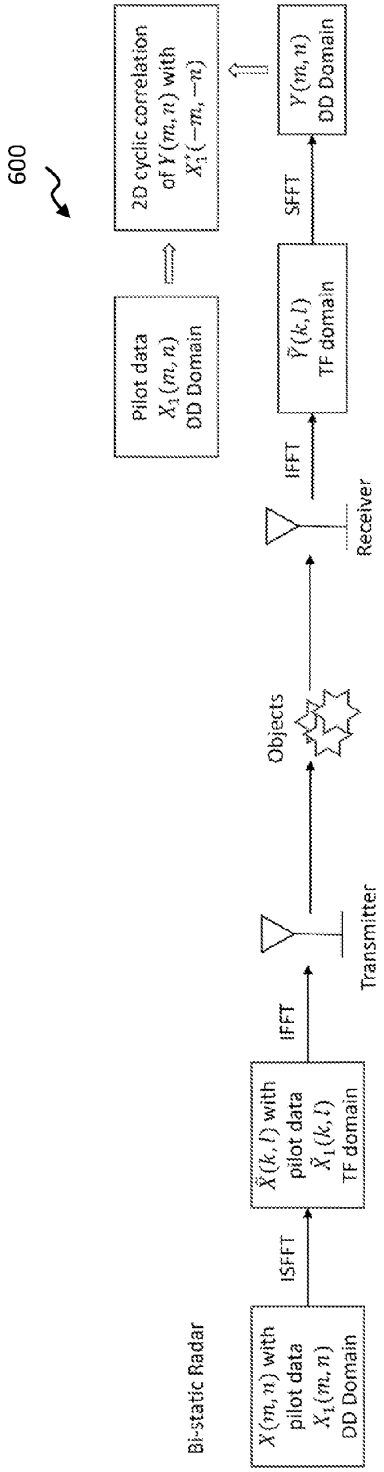
600
Bi-static Radar
$X(m,n)$ with pilot data $X_1(m,n)$ DD Domain
ISFFT
$\tilde{X}(k,l)$ with pilot data $\tilde{X}_1(k,l)$ TF domain
IFFT
Transmitter
Objects
Receiver
IFFT
$\tilde{Y}(k,l)$ TF domain
SFFT
$Y(m,n)$ DD Domain
Pilot data $X_1(m,n)$ DD Domain
2D cyclic correlation of $Y(m,n)$ with $X_1'(-m,-n)$

FIG. 6A

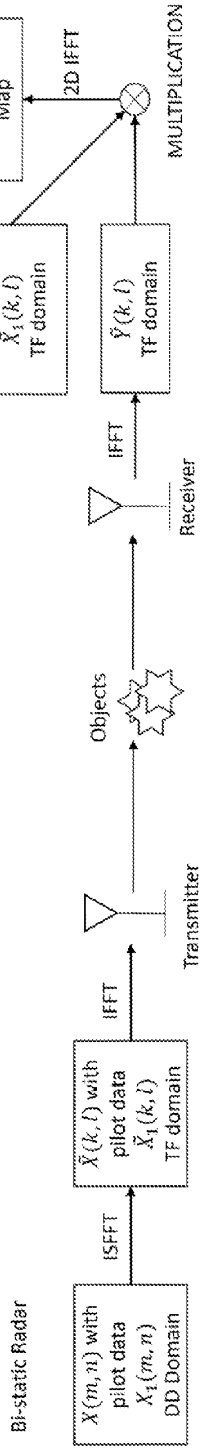
650
Bi-static Radar
$X(m,n)$ with pilot data $X_1(m,n)$ DD Domain
ISFFT
$\tilde{X}(k,l)$ with pilot data $\tilde{X}_1(k,l)$ TF domain
IFFT
Transmitter
Objects
Receiver
IFFT
$\tilde{Y}(k,l)$ TF domain
Pilot data $\tilde{X}_1(k,l)$ TF domain
2D IFFT
MULTIPLICATION
Range-Doppler Map

FIG. 6B

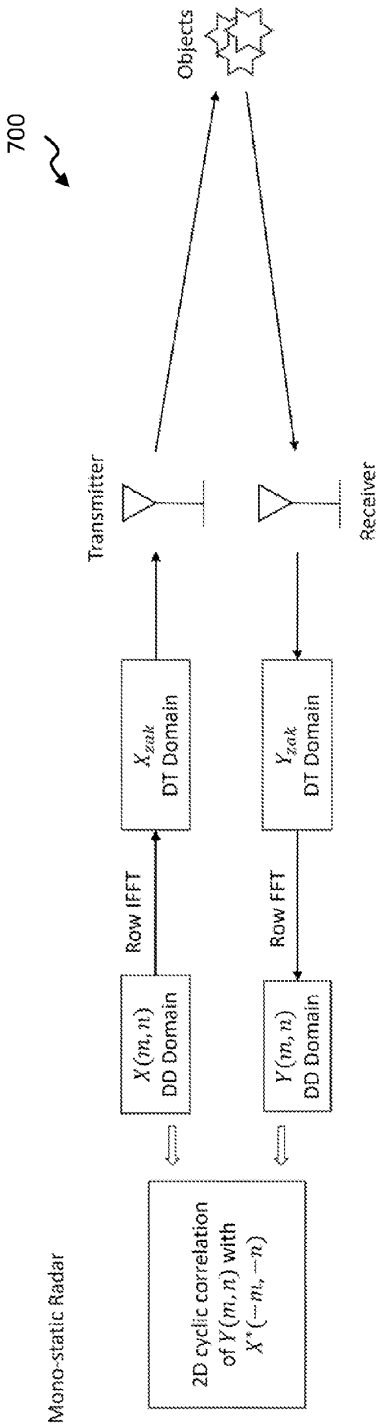
700
Objects
Transmitter
Receiver
$X_{zak}$ DT Domain
$Y_{zak}$ DT Domain
Row IFFT
Row FFT
$X(m,n)$ DD Domain
$Y(m,n)$ DD Domain
2D cyclic correlation of $Y(m,n)$ with $X^*(-m,-n)$
Mono-static Radar

FIG. 7A

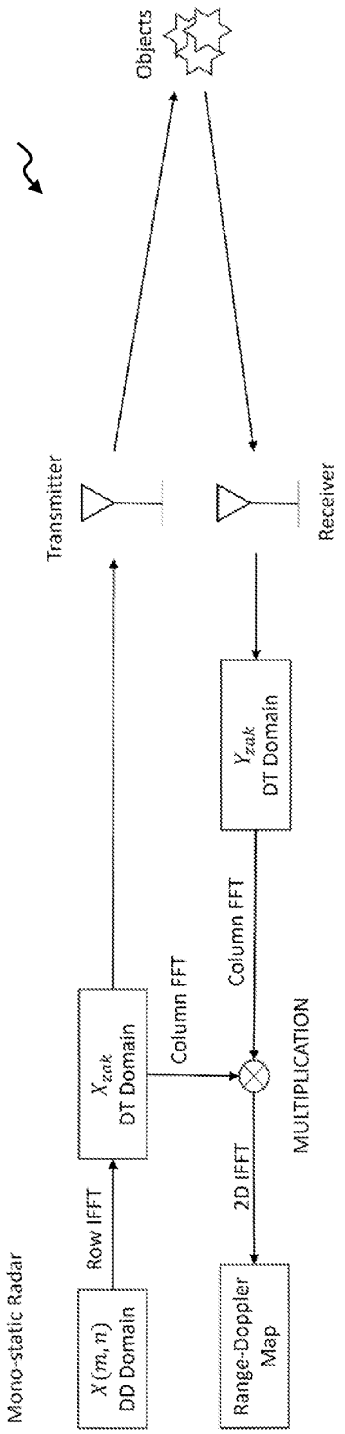
750
Objects
Transmitter
Receiver
$X_{zak}$ DT Domain
$Y_{zak}$ DT Domain
Row IFFT
Column FFT
Column FFT
MULTIPLICATION
2D IFFT
$X(m,n)$ DD Domain
Range-Doppler Map
Mono-static Radar

FIG. 7B

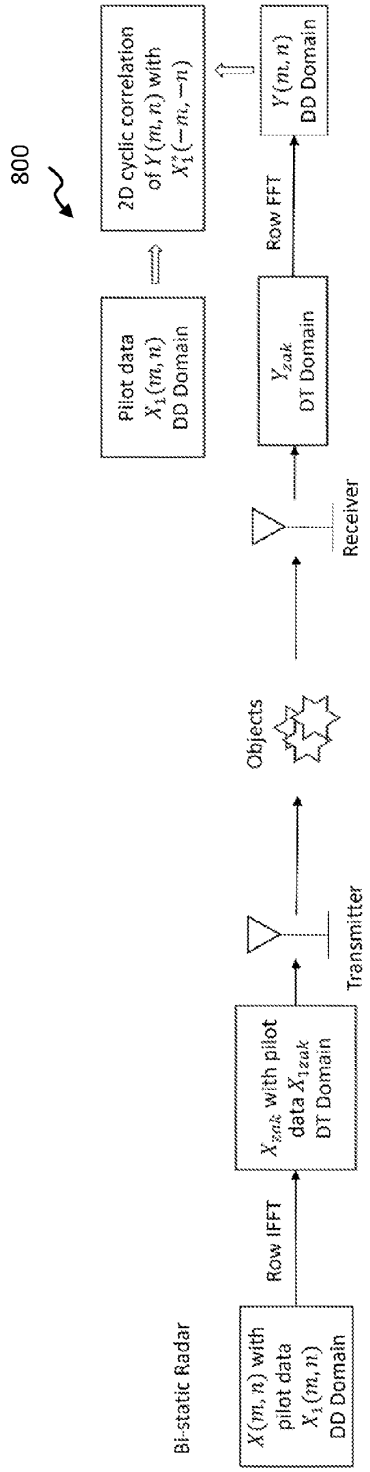
800
2D cyclic correlation of $Y(m,n)$ with $X_1^*(-m,-n)$
$Y(m,n)$ DD Domain
Pilot data $X_1(m,n)$ DD Domain
Row FFT
$Y_{zak}$ DT Domain
Receiver
Objects
Transmitter
$X_{zak}$ with pilot data $X_{1zak}$ DT Domain
Row IFFT
$X(m,n)$ with pilot data $X_1(m,n)$ DD Domain
Bi-static Radar

FIG. 8A

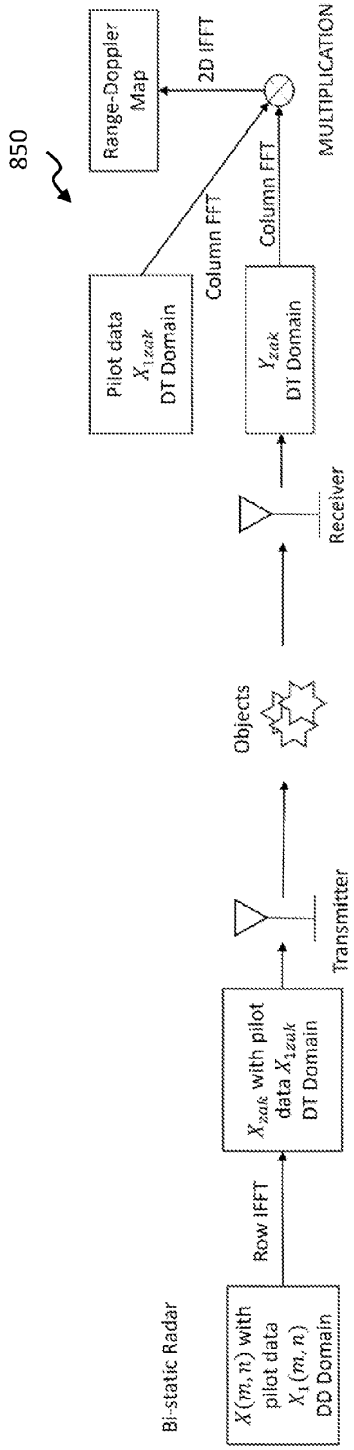
850
Range-Doppler Map
2D IFFT
MULTIPLICATION
Column FFT
Column FFT
Pilot data $X_{1zak}$ DT Domain
$Y_{zak}$ DT Domain
Receiver
Objects
Transmitter
$X_{zak}$ with pilot data $X_{1zak}$ DT Domain
Row IFFT
$X(m,n)$ with pilot data $X_1(m,n)$ DD Domain
Bi-static Radar

FIG. 8B

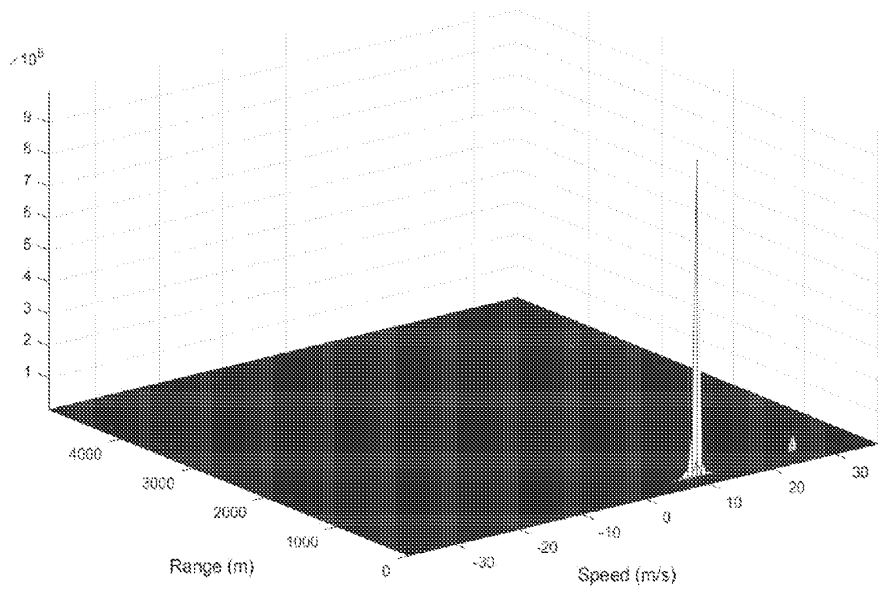
×10^6
9
8
7
6
5
4
3
2
1
4000
3000
2000
1000
0
Range (m)
-30
-20
-10
0
10
20
30
Speed (m/s)

FIG. 9

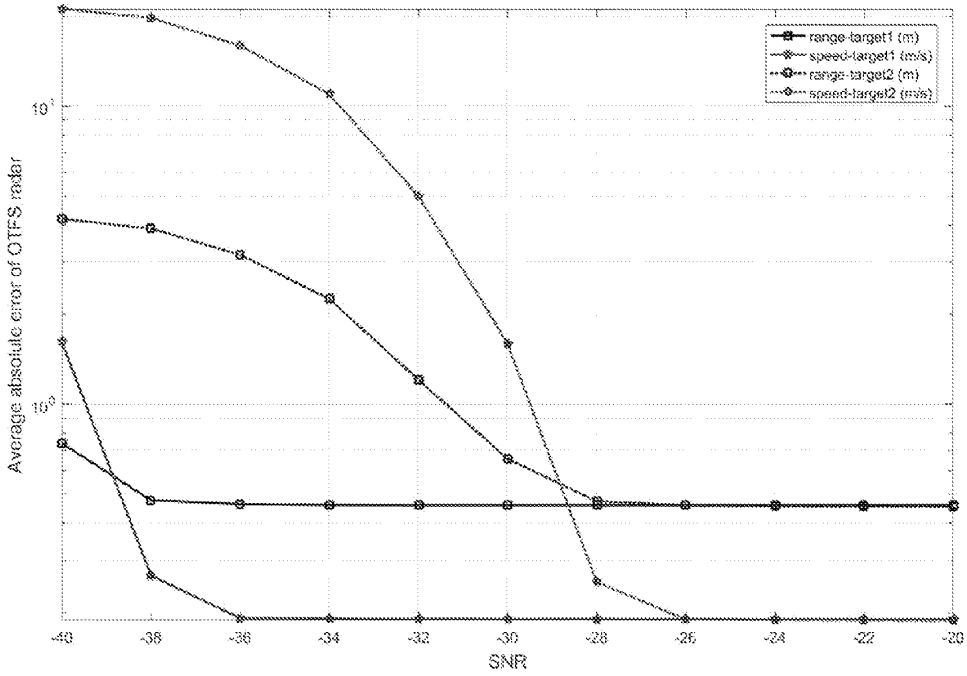
range-target1 (m)
speed-target1 (m/s)
range-target2 (m)
speed-target2 (m/s)
Average absolute error of OTFS radar
10^1
10^0
-40
-38
-36
-34
-32
-30
-28
-26
-24
-22
-20
SNR

FIG. 10

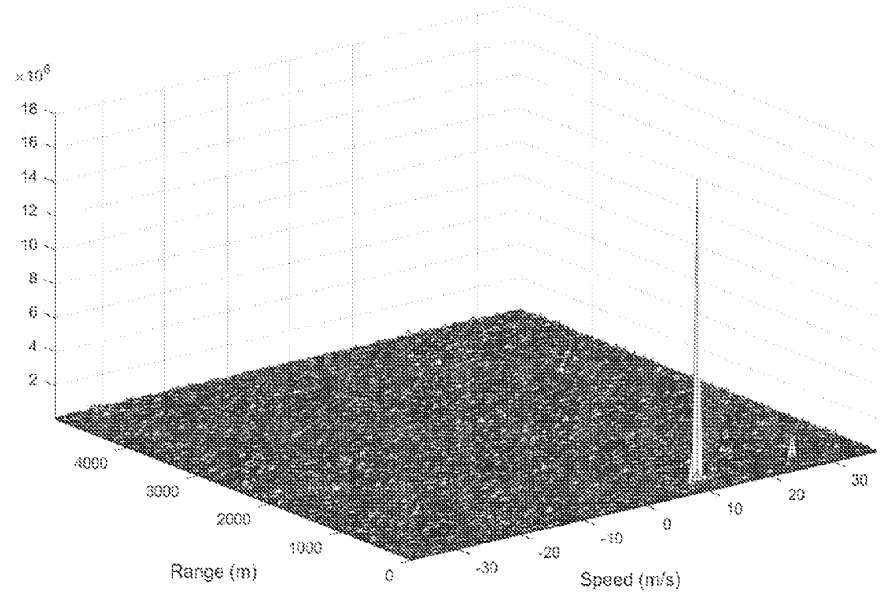
x 10^6
18
16
14
12
10
8
6
4
2
4000
3000
2000
1000
0
Range (m)
-30
-20
-10
0
10
20
30
Speed (m/s)

FIG. 11

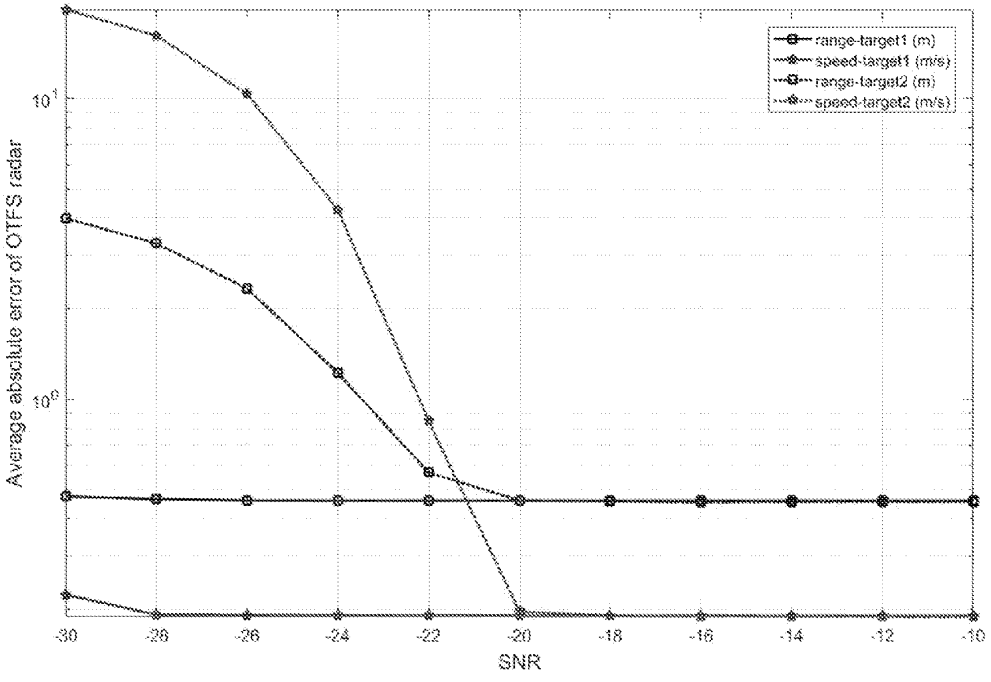
range-target1 (m)
speed-target1 (m/s)
range-target2 (m)
speed-target2 (m/s)
Average absolute error of OTFS radar
10^1
10^0
-30
-28
-26
-24
-22
-20
-18
-16
-14
-12
-10
SNR

FIG. 12

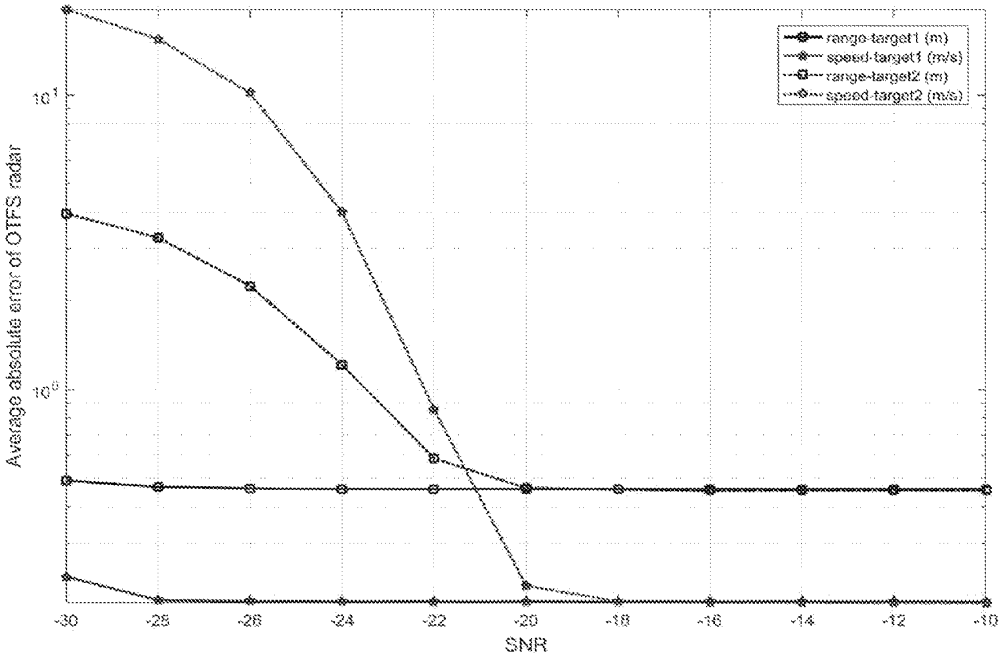
range-target1 (m)
speed-target1 (m/s)
range-target2 (m)
speed-target2 (m/s)
Average absolute error of OTFS radar
SNR
-30
-28
-26
-24
-22
-20
-18
-16
-14
-12
-10

FIG. 13

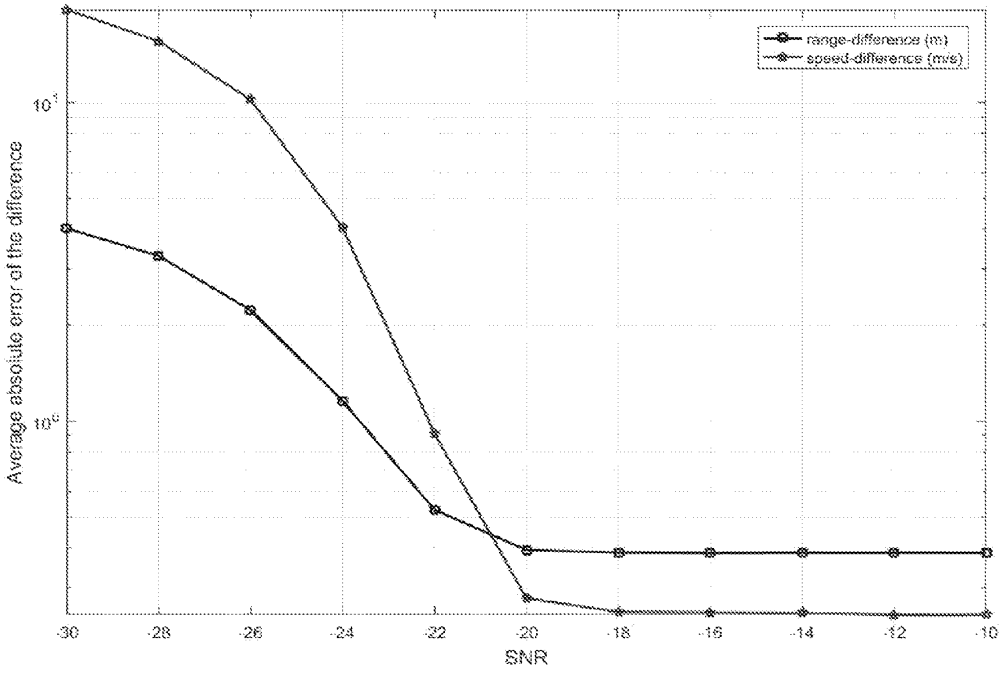
range-difference (m)
speed-difference (m/s)
Average absolute error of the difference
SNR
-30
-28
-26
-24
-22
-20
-18
-16
-14
-12
-10

FIG. 14

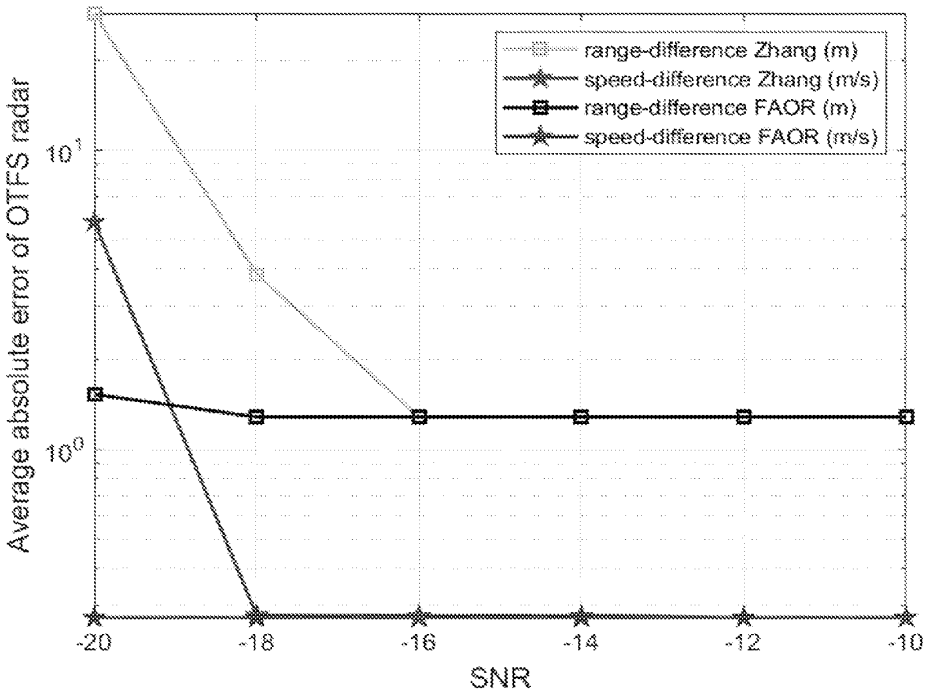
range-difference Zhang (m)
speed-difference Zhang (m/s)
range-difference FAOR (m)
speed-difference FAOR (m/s)
Average absolute error of OTFS radar
$10^1$
$10^0$
-20
-18
-16
-14
-12
-10
SNR

FIG. 15

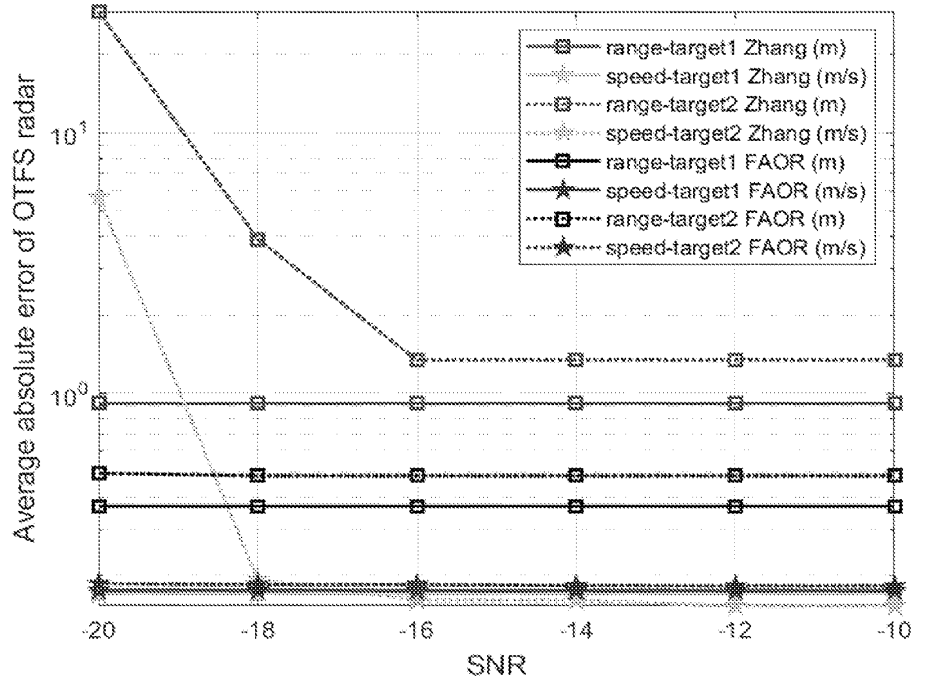
range-target1 Zhang (m)
speed-target1 Zhang (m/s)
range-target2 Zhang (m)
speed-target2 Zhang (m/s)
range-target1 FAOR (m)
speed-target1 FAOR (m/s)
range-target2 FAOR (m)
speed-target2 FAOR (m/s)
Average absolute error of OTFS radar
$10^1$
$10^0$
-20
-18
-16
-14
-12
-10
SNR

FIG. 16