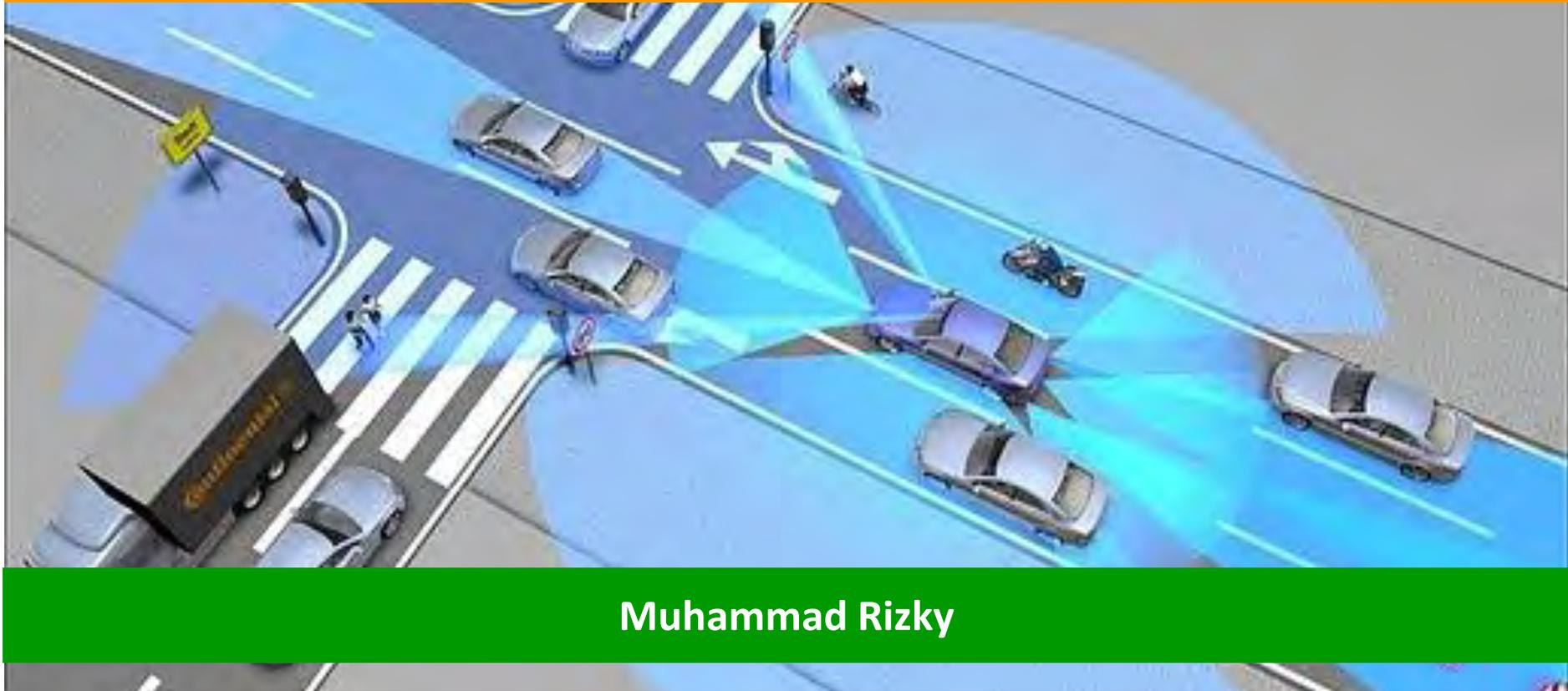


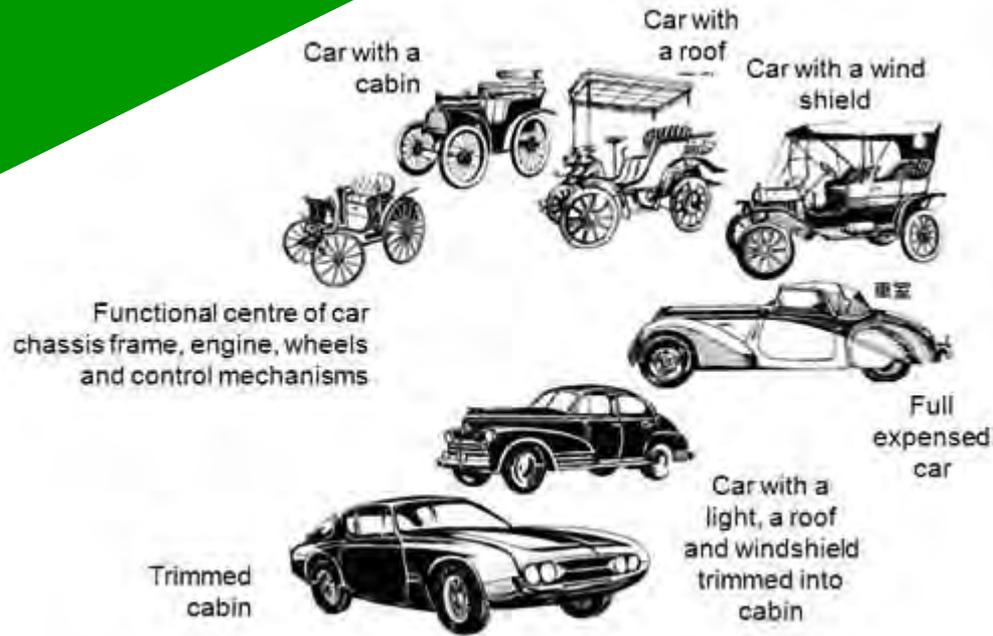
DESAIN GELOMBANG RADAR MIMO MENGUNAKAN TEKNIK *INTERLEAVED-OFDM*



Muhammad Rizky

Dosen Pembimbing : Prof. Ir. Gamantyo Hendranto, M.Eng., Ph.D.
Devy Kuswidiastuti, S.T., M.Sc.

Perkembangan Kendaraan Bermotor





Adaptive Cruise Control (ACC)



**ACC Stop&Go
Collision Mitigation /
Precrash**



Park Assist



Lane Change Assist

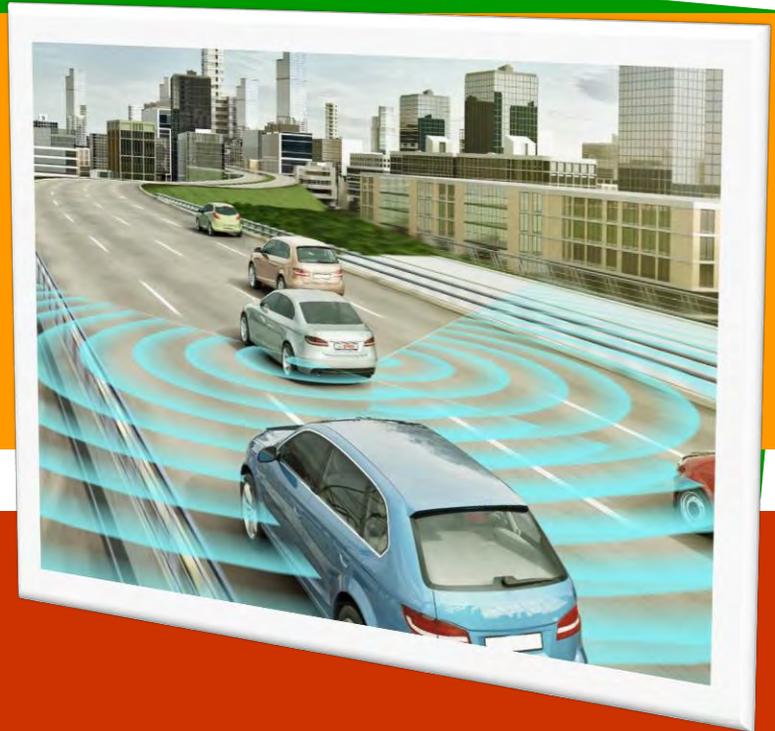


AUTOMOTIVE RADAR

Automotive Radar

Mampu mendeteksi Jarak,
Kecepatan, dan Sudut
Kedatangan Target

Memiliki Level *Sidelobe*
yang rendah



Tahan Terhadap Interferensi

Tujuan

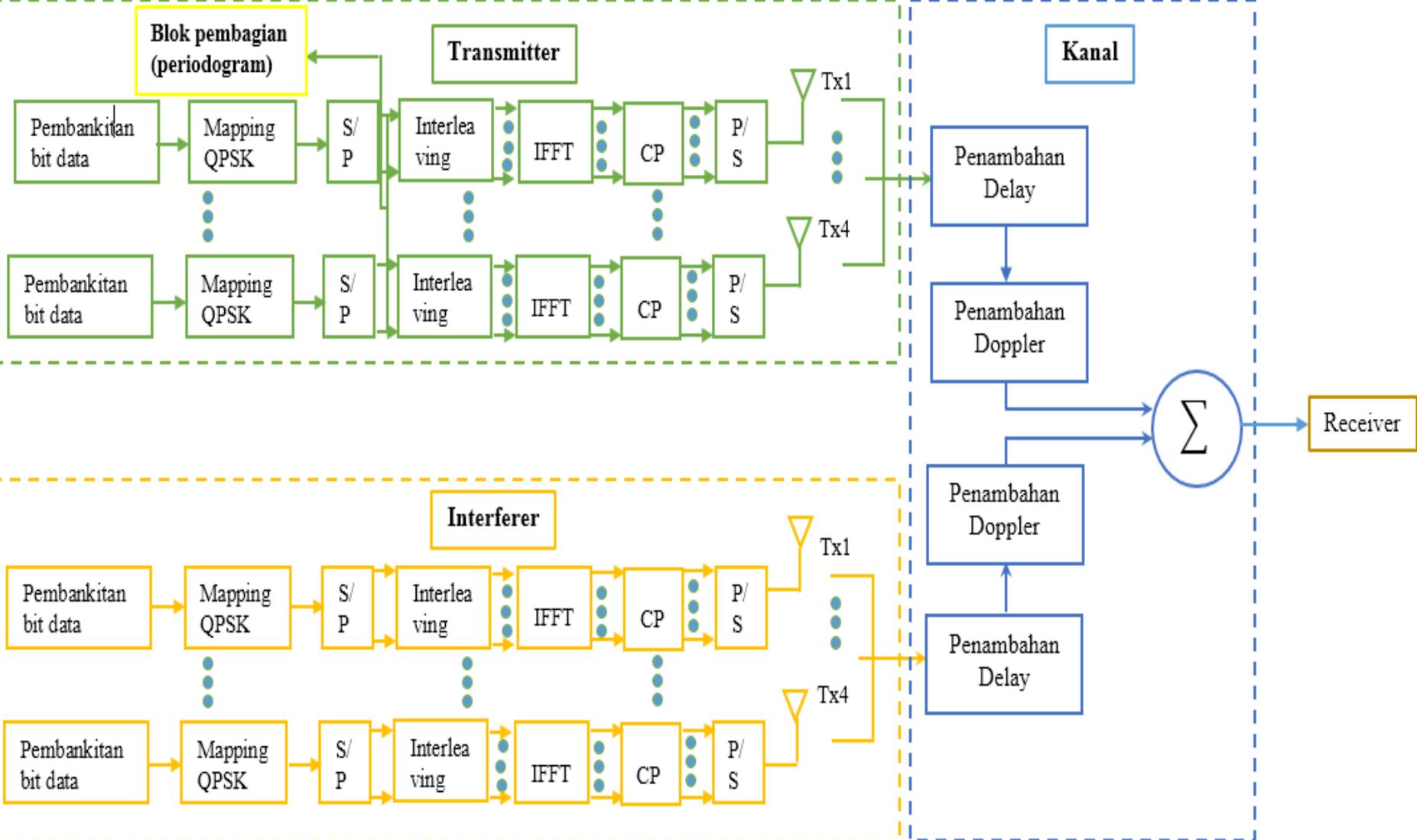


Menganalisis kemampuan radar MIMO-IOFDM dalam mendeteksi jarak, kecepatan, dan arah kedatangan dari target

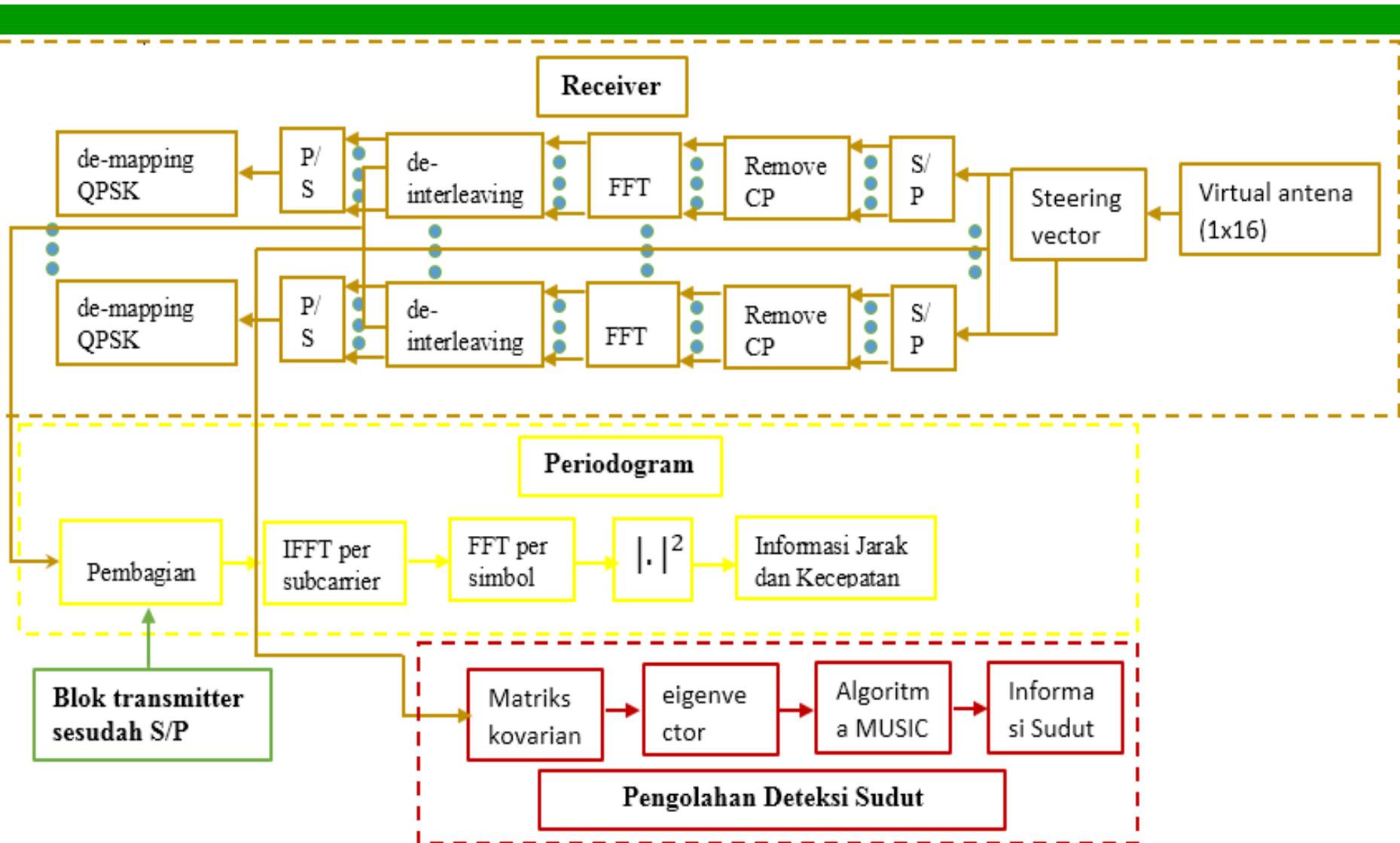
Menganalisis dampak dari interferensi antar user, terhadap resolusi dan akurasi jarak, kecepatan, dan arah kedatangan.

Menganalisis bentuk modifikasi teknik sinyal OFDM yang paling tahan terhadap interferensi.

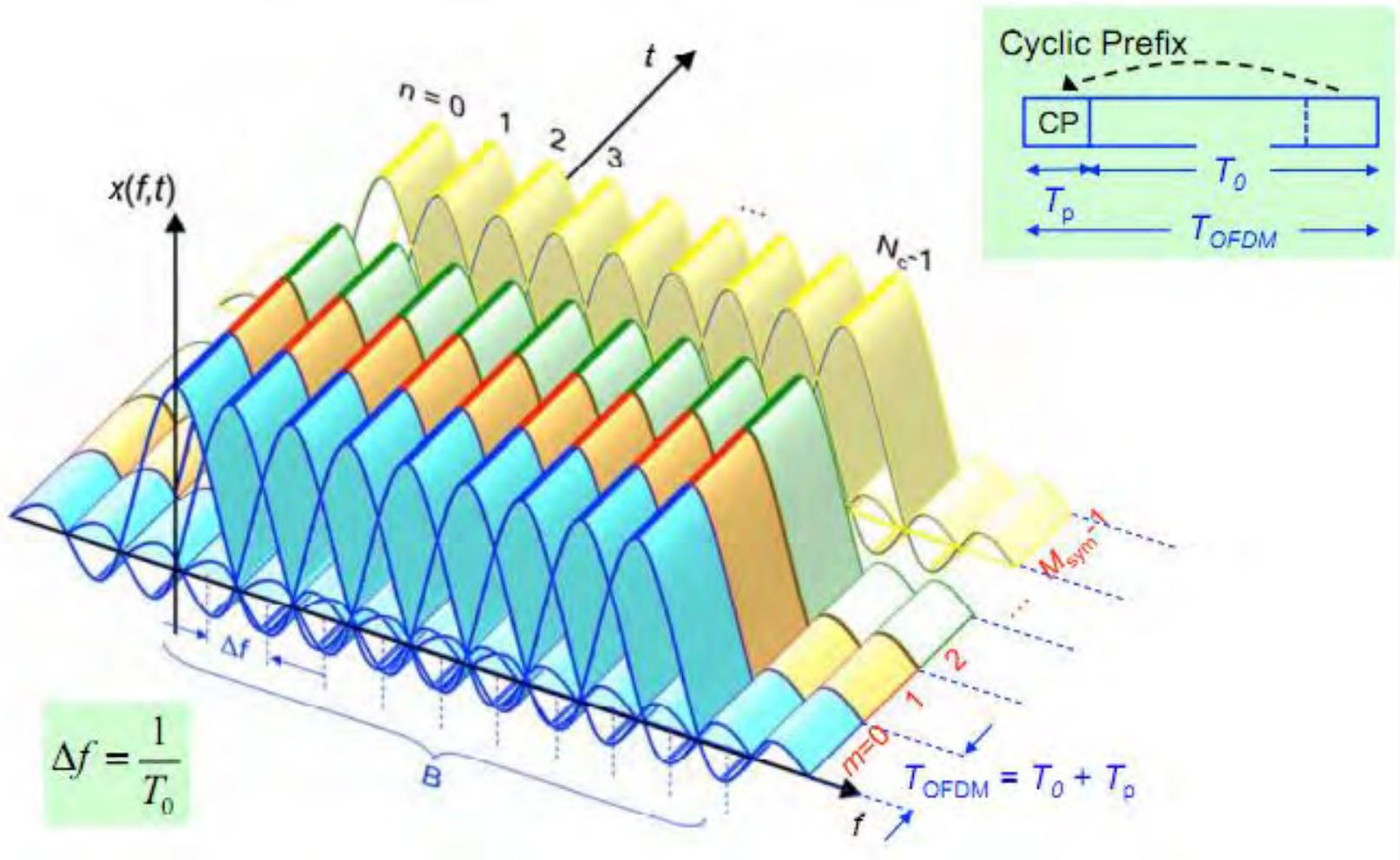
Metode Penelitian



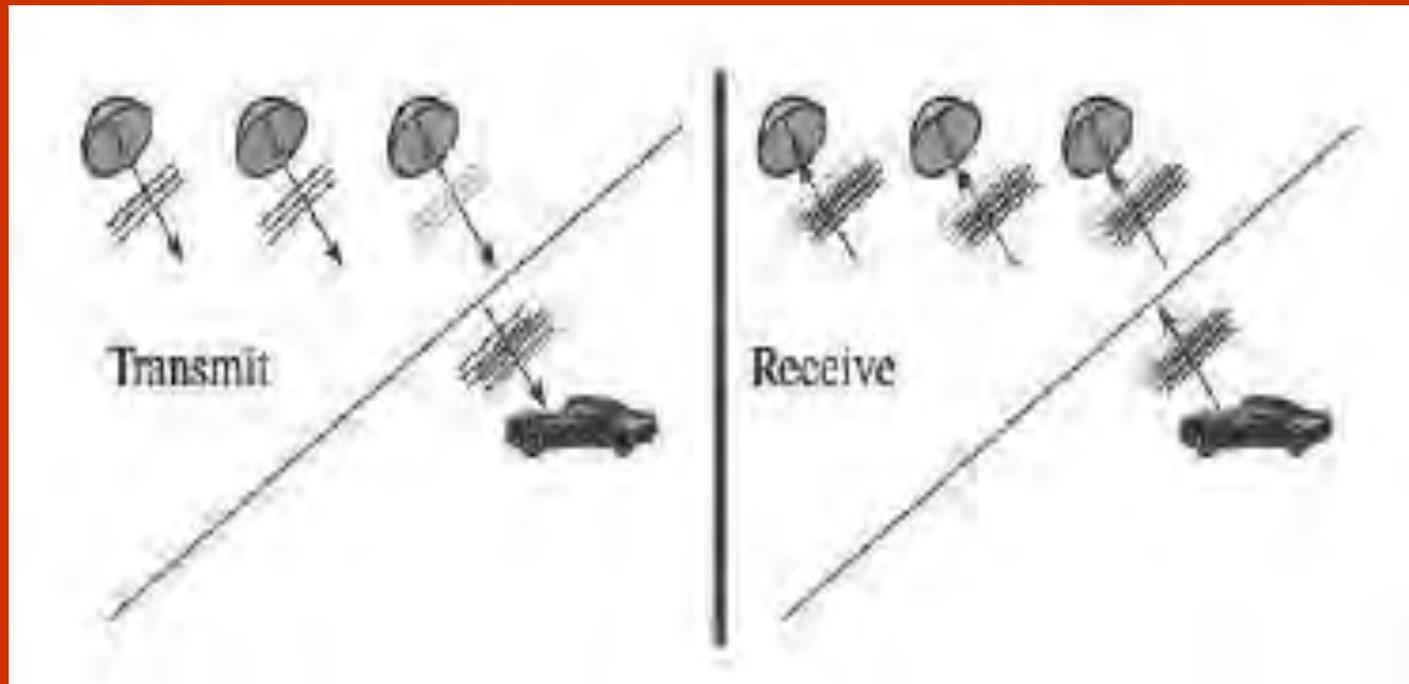
Metode Penelitian



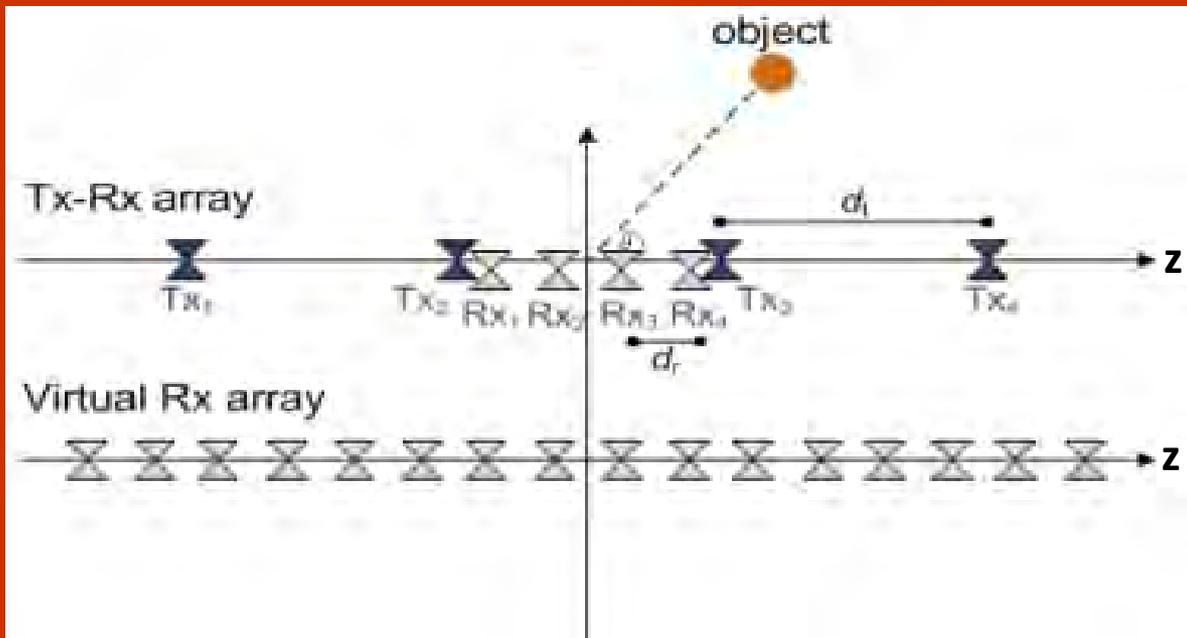
Sinyal OFDM



Sistem MIMO Radar

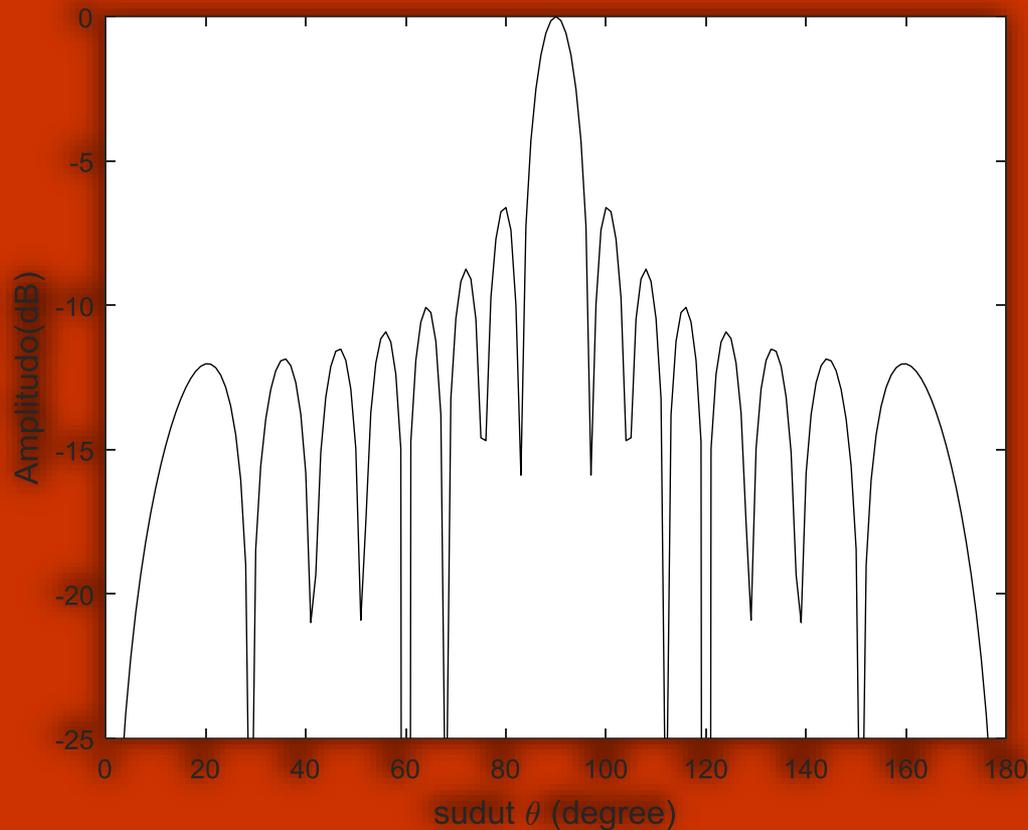


Virtual Antenna



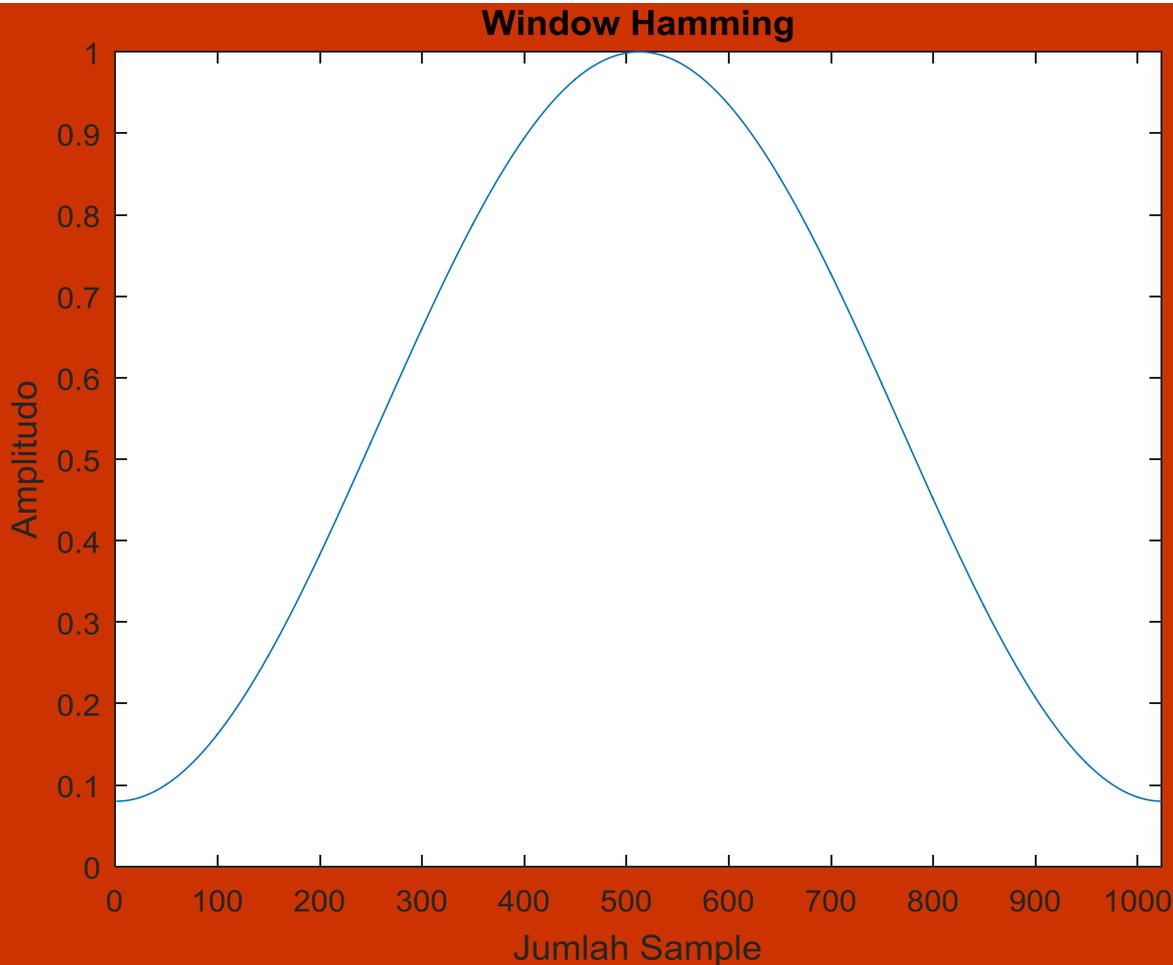
Penggunaan *Virtual Antenna* bertujuan untuk meningkatkan resolusi sudut dan meningkatkan jumlah target yang bisa diterima oleh sistem radar. Saat menggunakan algoritma MUSIC, jumlah deteksi maksimum adalah $M_r - 1$ sehingga saat MIMO berukuran 4×4 hanya bisa mendeteksi 3 target. Dengan menggunakan *virtual antenna* 16 elemen maka mampu mendeteksi 15 target

Pola Radiasi 16 Elemen



jika target berada pada sudut 90° maka level daya yang diterima bernilai tertinggi. Sedangkan saat target berada di sudut yang merupakan hasil pencerminan, seperti 80° dengan 100° , 70° dengan 110° , 60° dengan 120° , dst maka level daya yang diterima akan bernilai sama. Sedangkan jika sudut kedatangan target mendekati 90° maka nilainya akan semakin besar, namun jika sudut kedatangan target mendekati 0° dan 180° maka level daya yang diterima akan semakin menurun.

Window Hamming



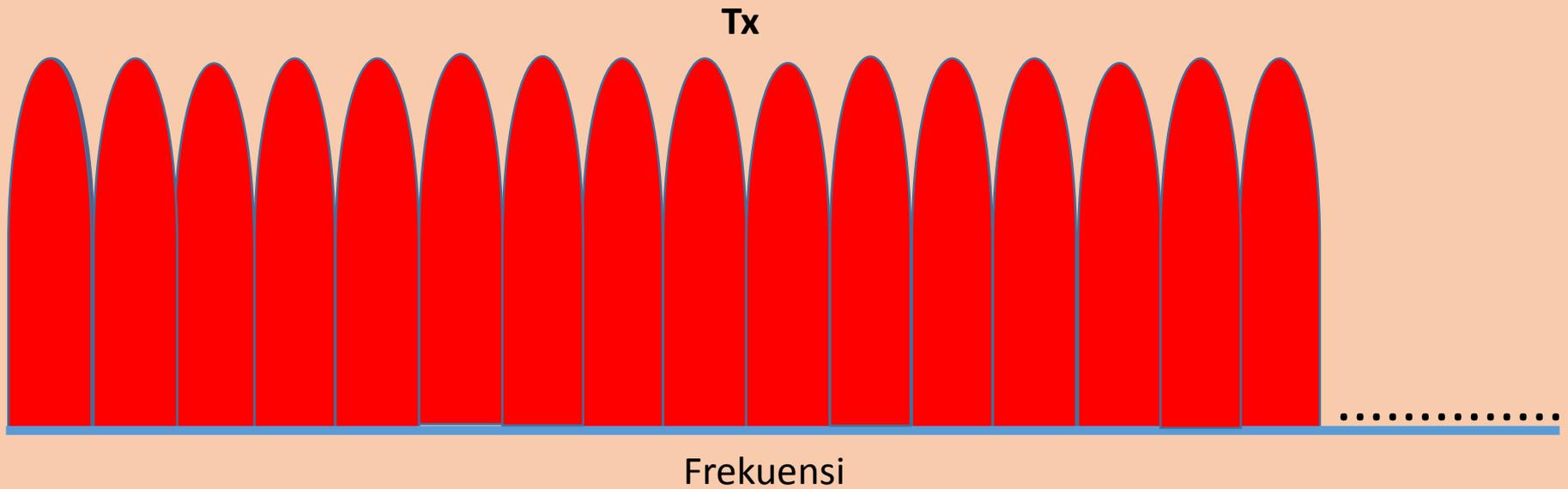
$$\omega_h(n) = \begin{cases} 0.54 - 0.46\cos\left(\frac{2\pi n}{N}\right) & \text{when } n \in \{0, \dots, N-1\} \\ 0 & \text{otherwise} \end{cases}$$

Secara umum, window merupakan deretan koefisien yang digunakan untuk pembobotan sinyal, biasanya ketika resolusi frekuensi meningkat maka terjadi: Mainlobe akan menjadi lebih sempit

Dan sidelobe menjadi lebih kecil

Sayangnya, menurunkan level sidelobe selalu menjadikan main lobe semakin lebar jadi selalu ada *trade off* untuk hal ini. Untuk tugas akhir ini akan menggunakan window hamming yang merupakan salah satu window yang sering digunakan, berikut adalah persamaan matematis dari window hamming:

SISO OFDM

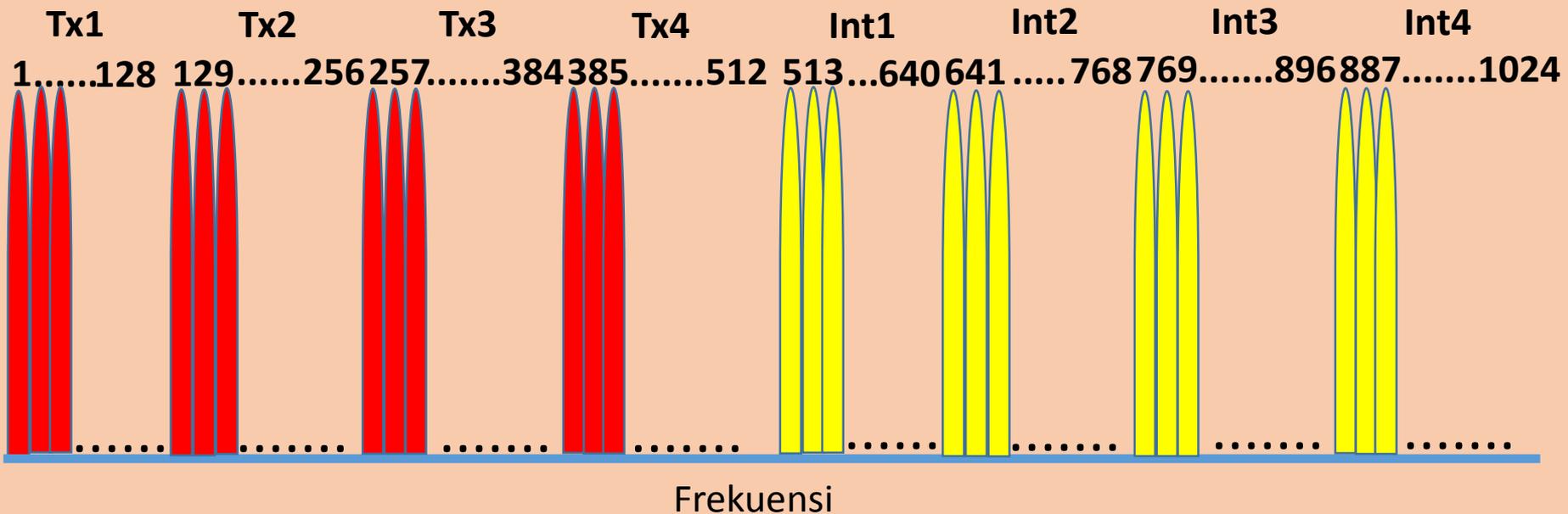


Subcarrier yang digunakan adalah 1024



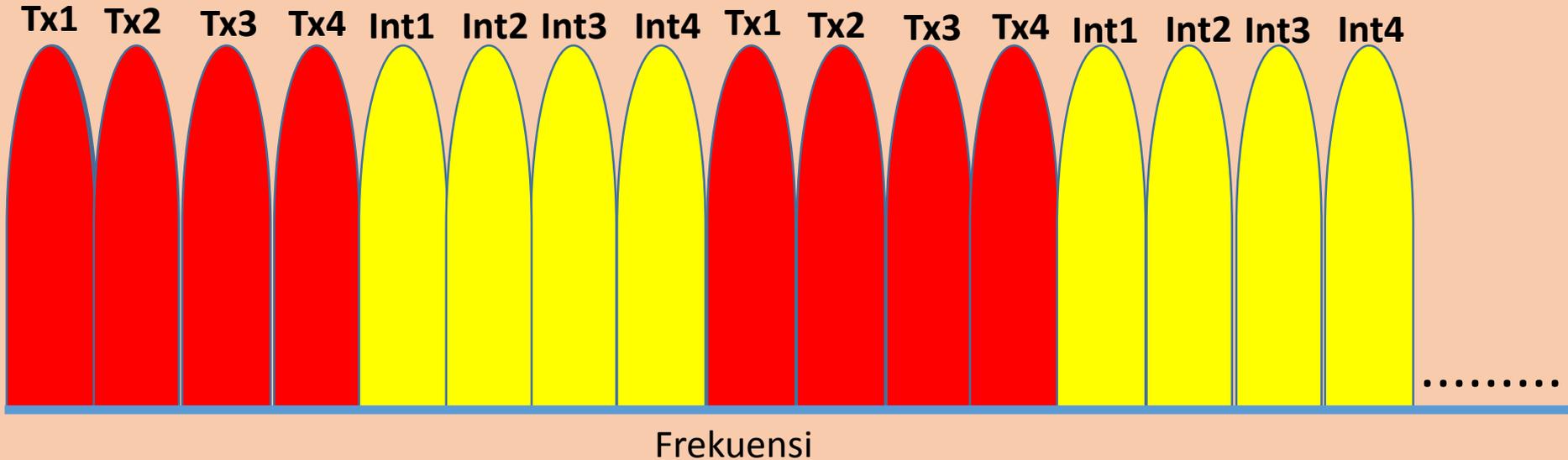
**Modifikasi
Radar
MIMO-OFDM**

Konsep MIMO-OFDM Konvensional



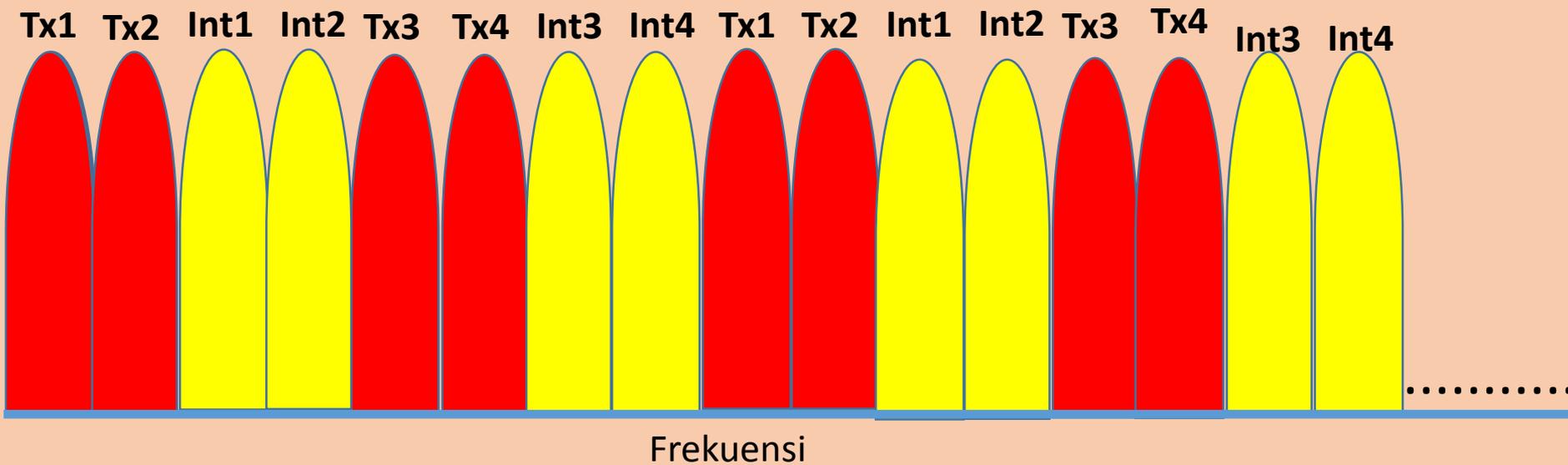
Setiap antenna pemancar memiliki 128 subcarrier

Konsep MIMO-IOFDM Wiesbeck



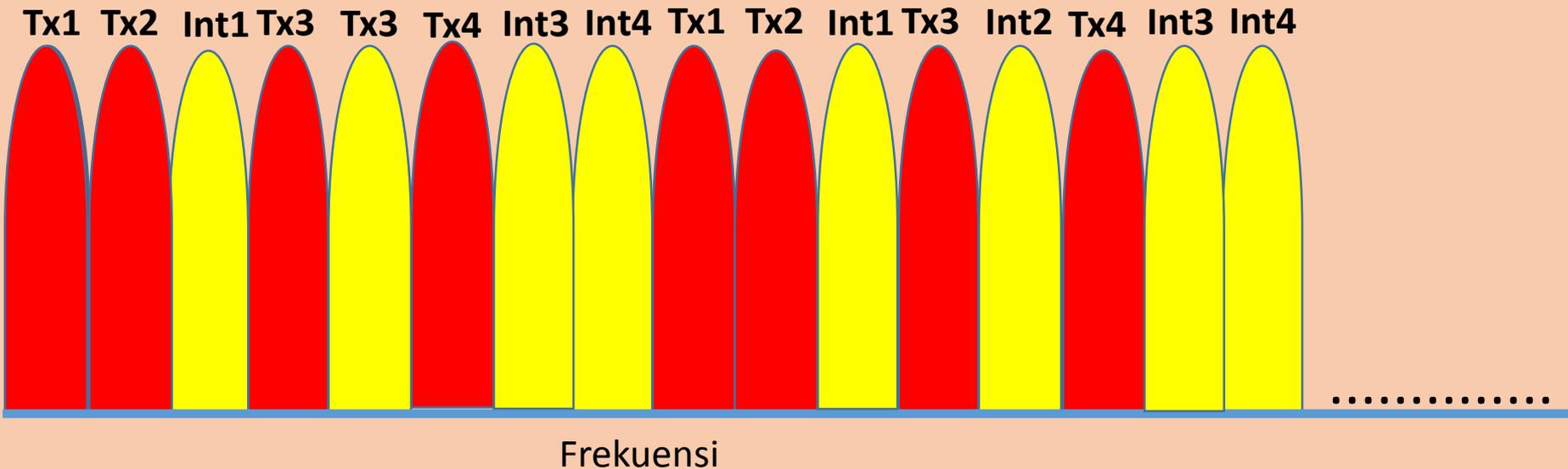
Setiap antena pemancar memiliki 128 subcarrier

Konsep MIMO-IOFDM Yoke



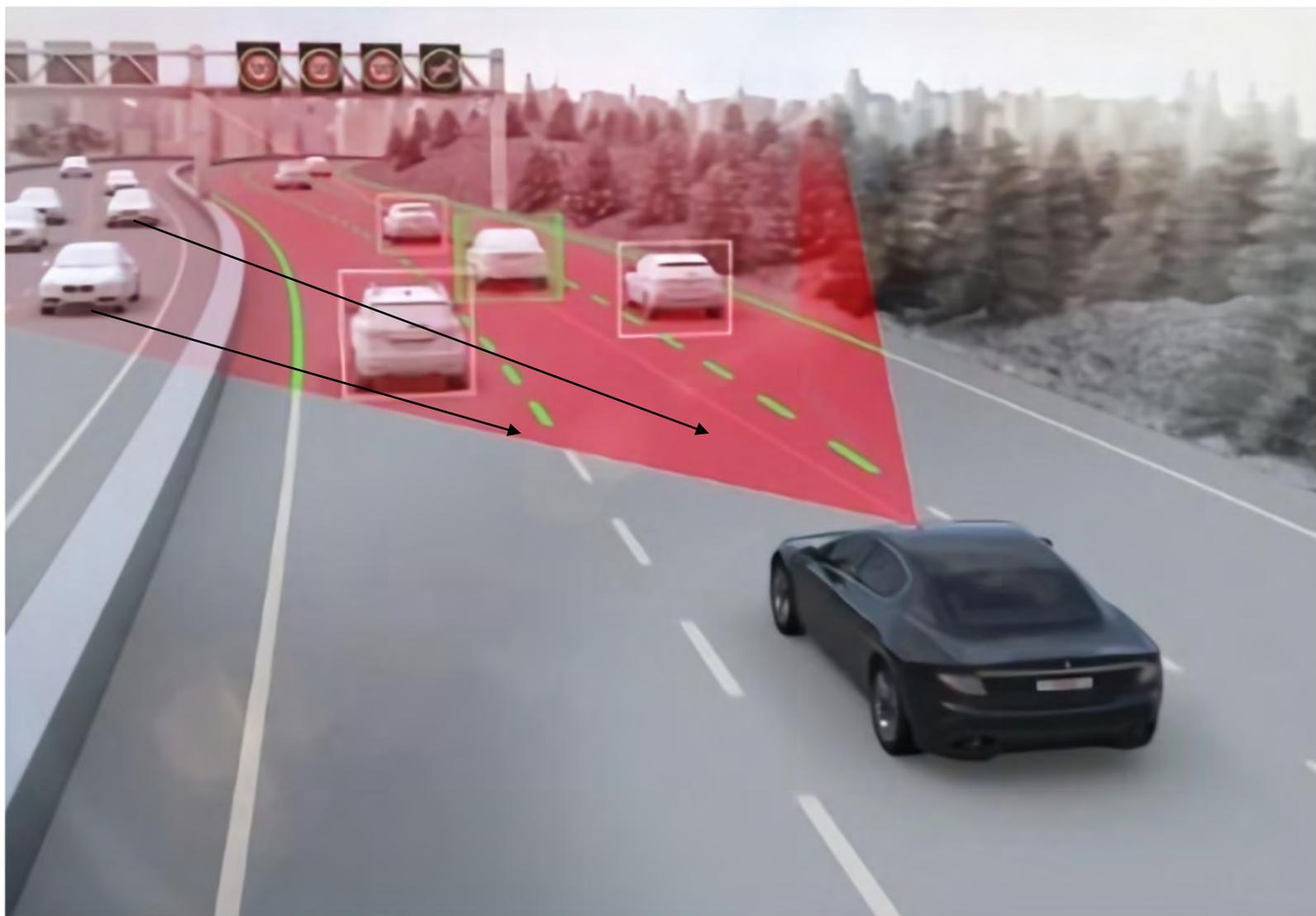
Setiap antena pemancar memiliki 128 subcarrier

Konsep MIMO-IOFDM *Subcarrier Acak*

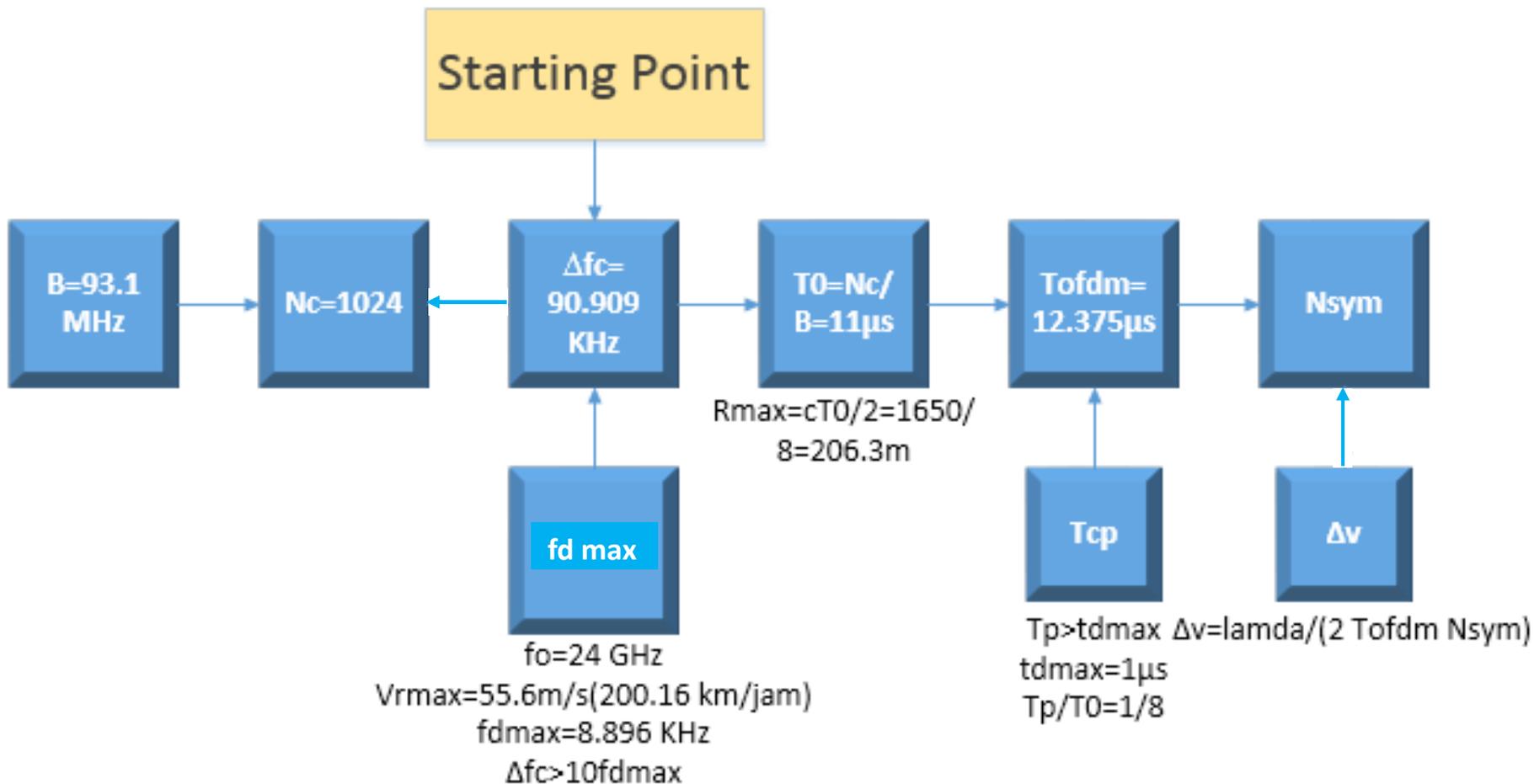


Setiap antenna pemancar memiliki 128 subcarrier

Skenario Radar



Spesifikasi Radar OFDM



Tabel Spesifikasi Radar IOFDM

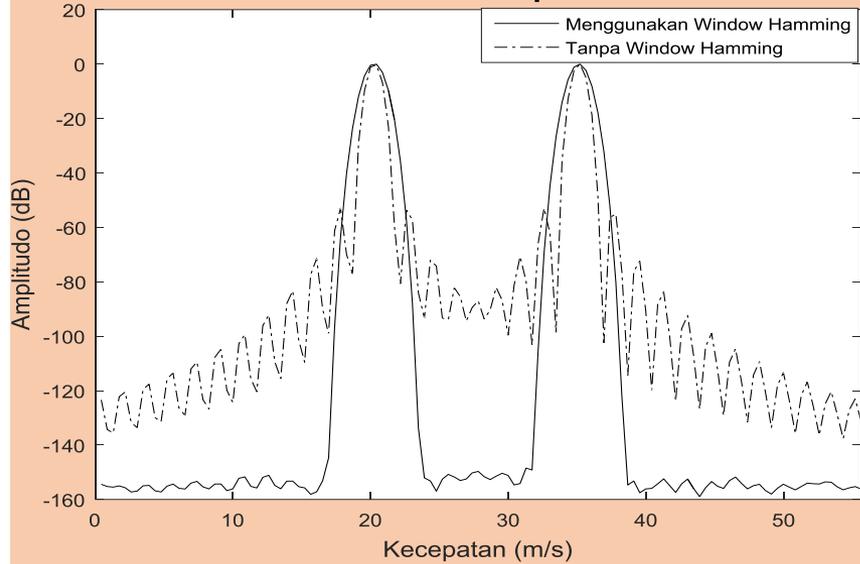
Simbol	Parameter	Nilai
M	Ukuran MIMO	4x4
f_c	Frekuensi carrier	24 GHz
Nc	Jumlah Subcarrier	1024
Nct	Jumlah subcarrier/transmitter	128
Nch	Jumlah channel	8
T	Durasi OFDM dasar	11 μ s
T_{cp}	Durasi Cyclic prefix	1.375 μ s
T_{sym}	Total durasi simbol OFDM	12.375 μ s
B	Bandwidth	93.1 MHz
Δr	Resolusi jarak	1.61 m
R_{max}	Maksimum jarak	206.3 m
V_{max}	Maksimum kecepatan	55.6 m/s
Nsym	Jumlah simbol	256
Δv	Resolusi kecepatan	1.97 m/s
$\Delta \theta$	Resolusi Sudut	0.05 $^\circ$



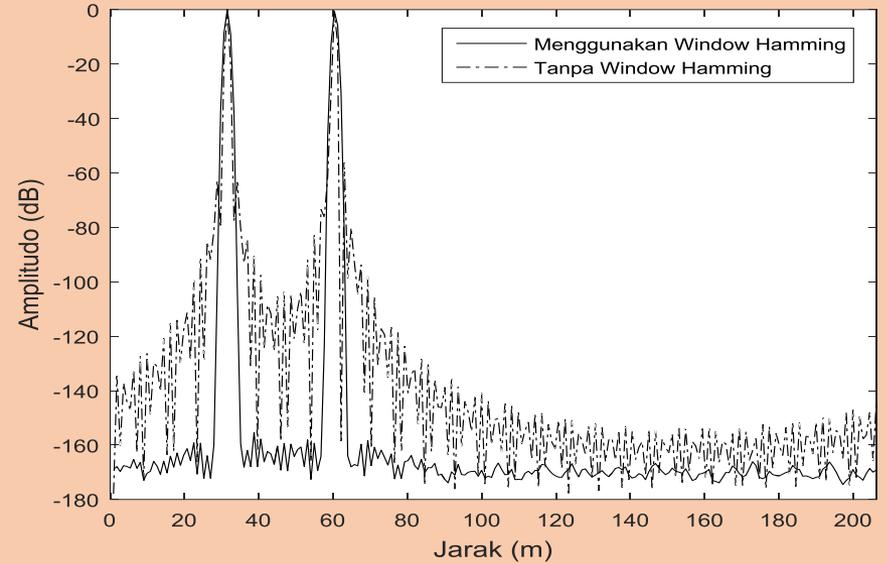
**Analisis dan
Pembahasan**

Analisis Efek Window Hamming

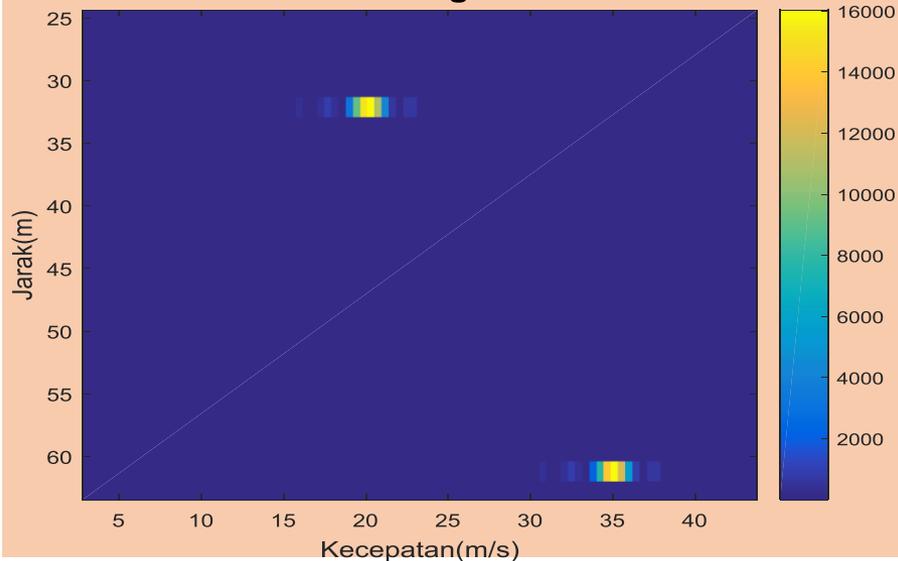
Deteksi Kecepatan



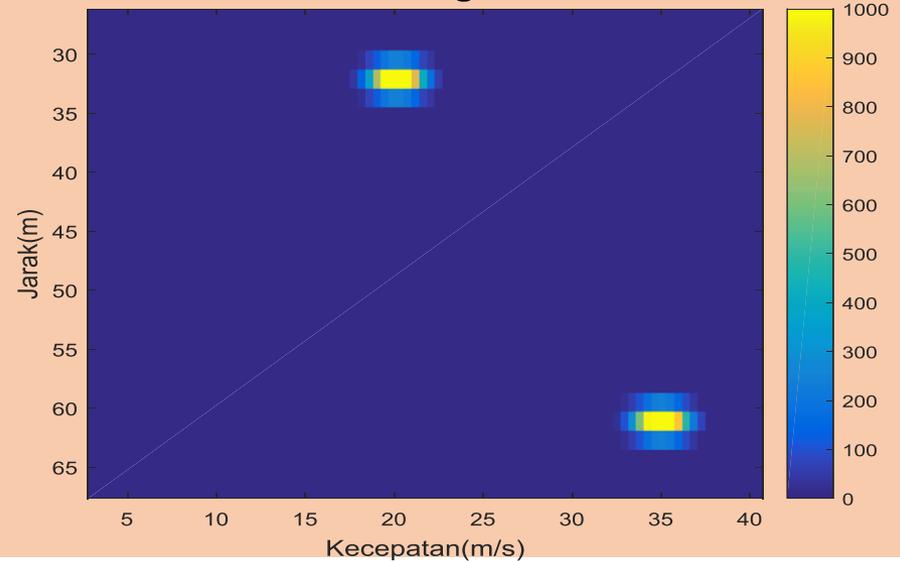
Deteksi Jarak



Plot Ambiguitas

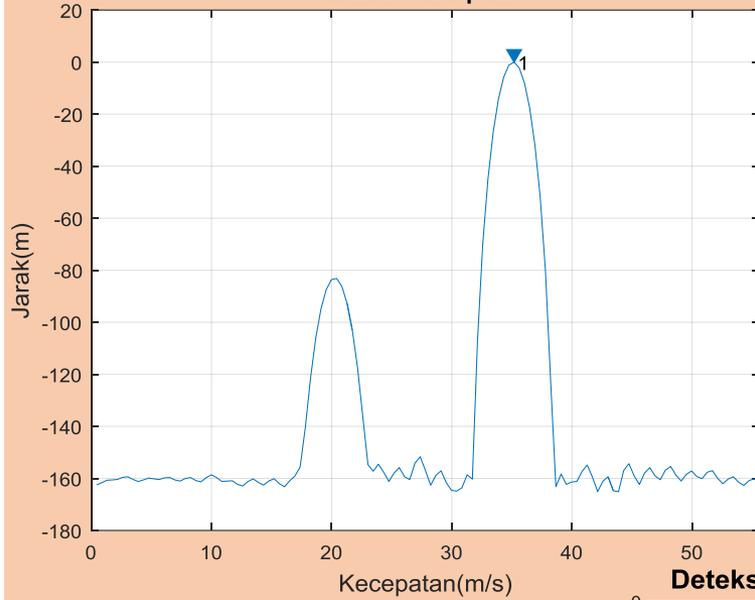


Plot Ambiguitas

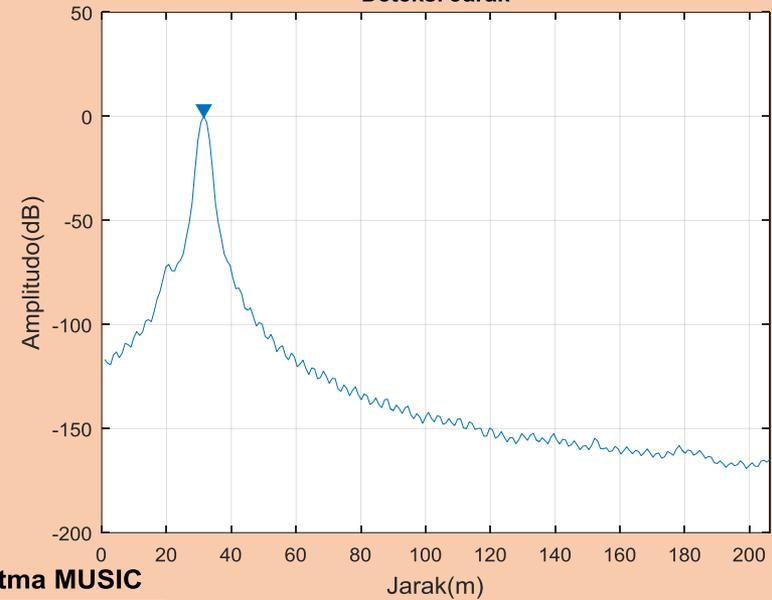


Analisis Efek DoA

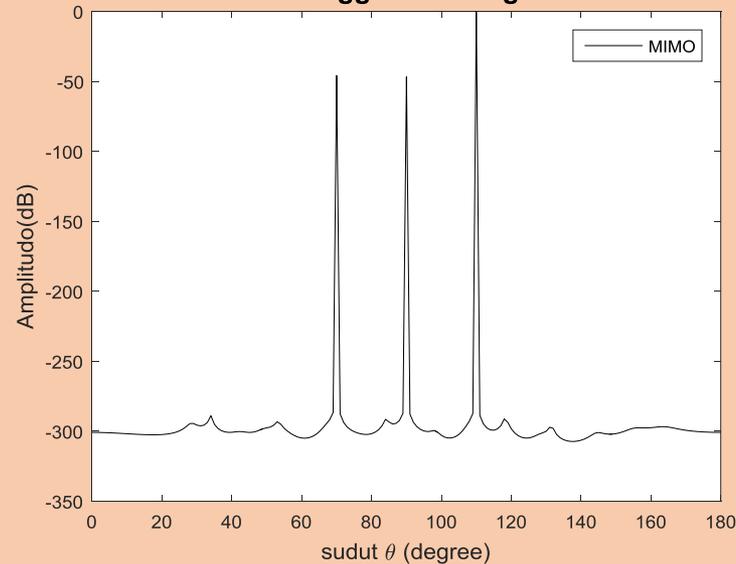
Deteksi Kecepatan



Deteksi Jarak

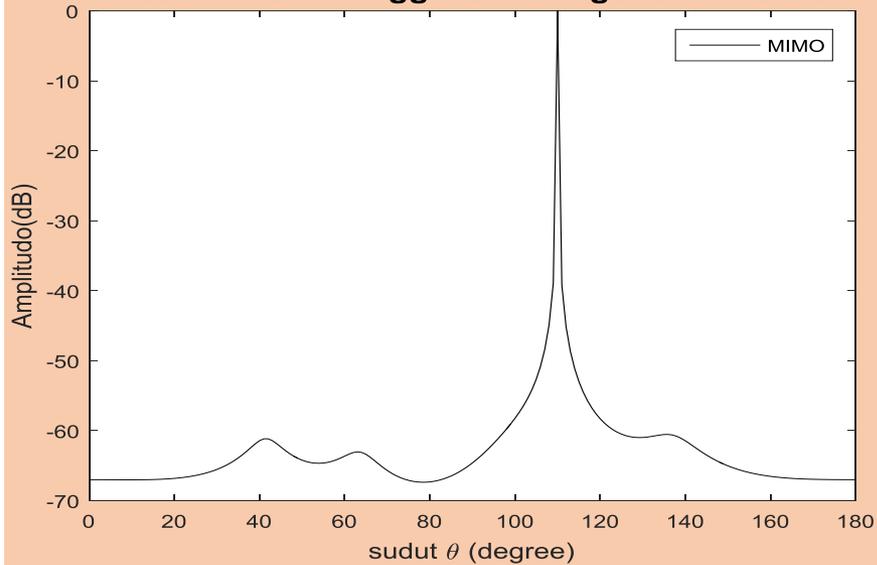


Deteksi DoA Menggunakan Algoritma MUSIC

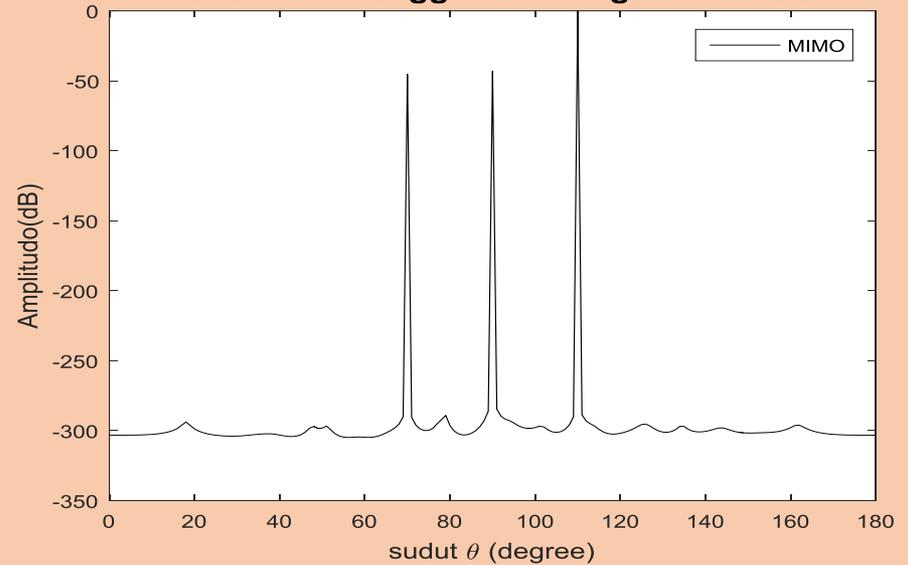


Analisis Efek *Virtual Array*

Deteksi DoA Menggunakan Algoritma MUSIC

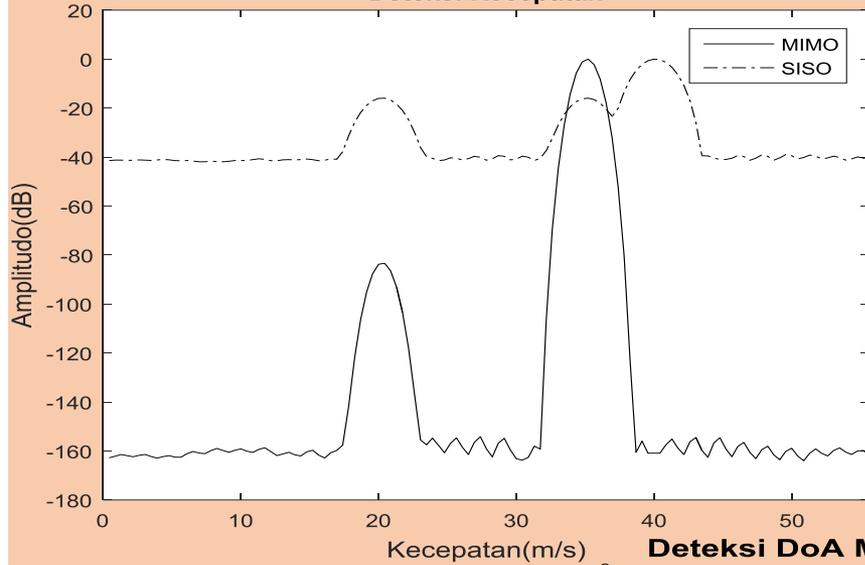


Deteksi DoA Menggunakan Algoritma MUSIC

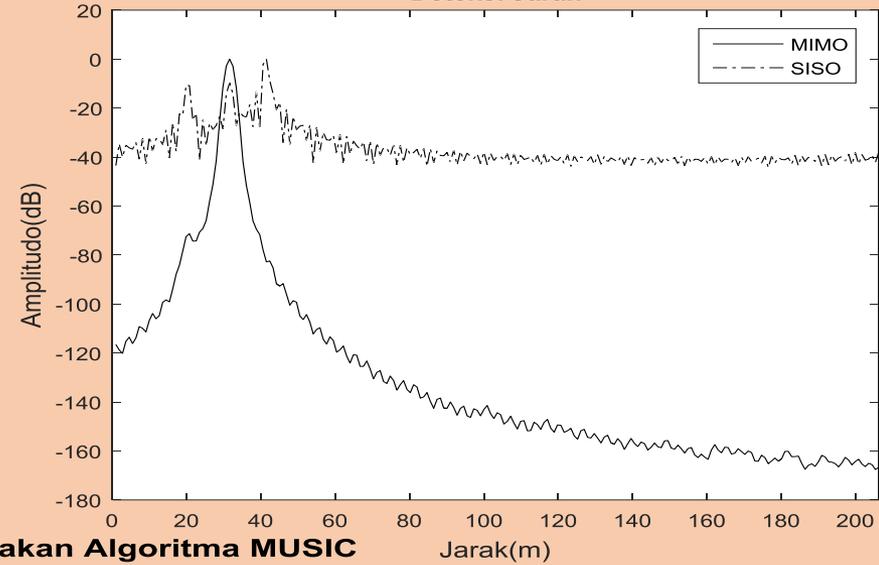


Analisis MIMO OFDM Konvensional vs SISO OFDM

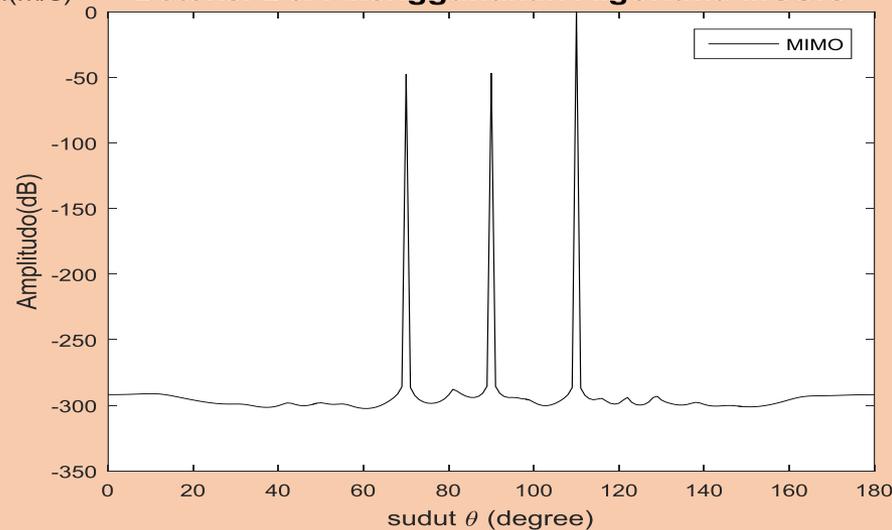
Deteksi Kecepatan



Deteksi Jarak

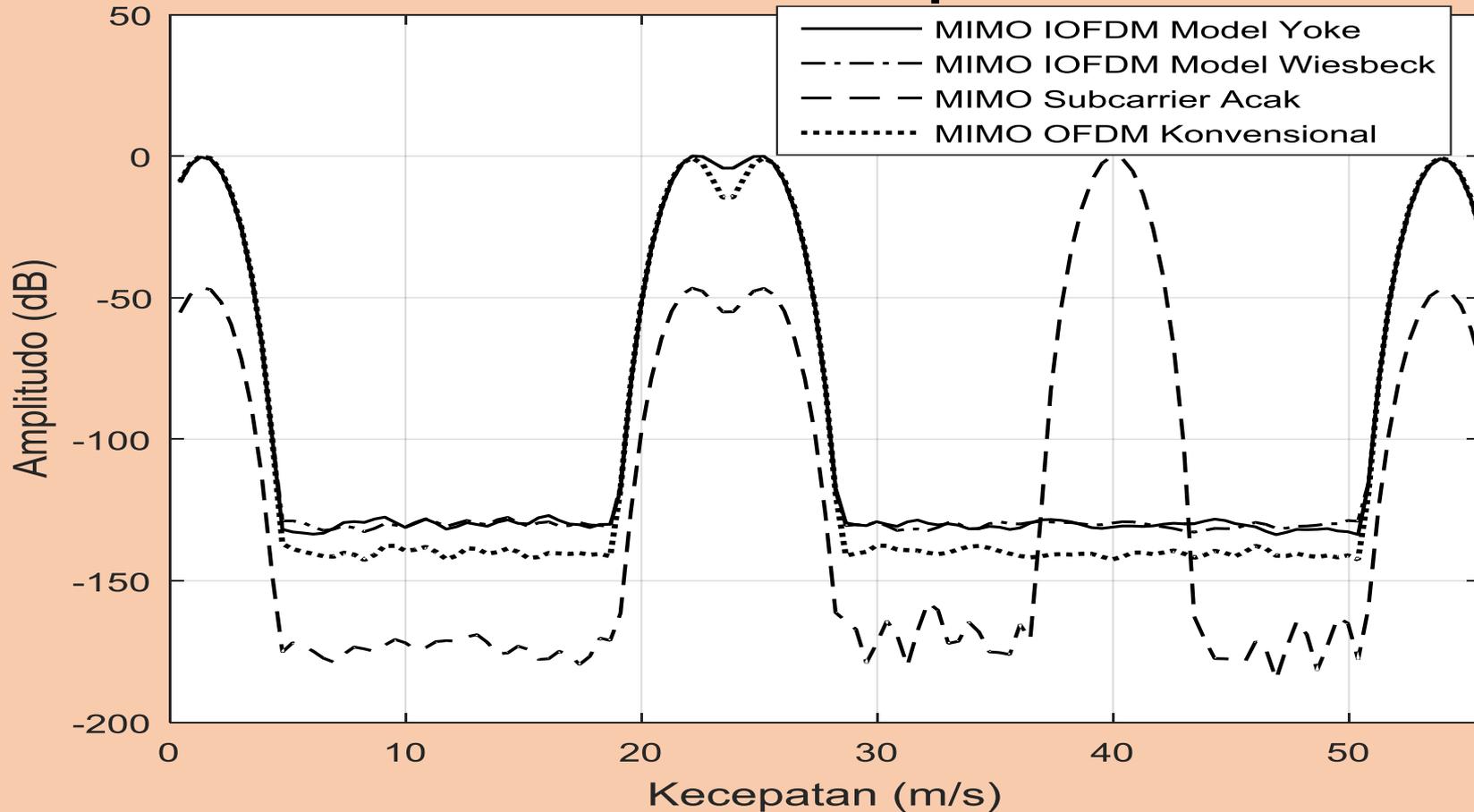


Deteksi DoA Menggunakan Algoritma MUSIC



Analisis MIMO OFDM

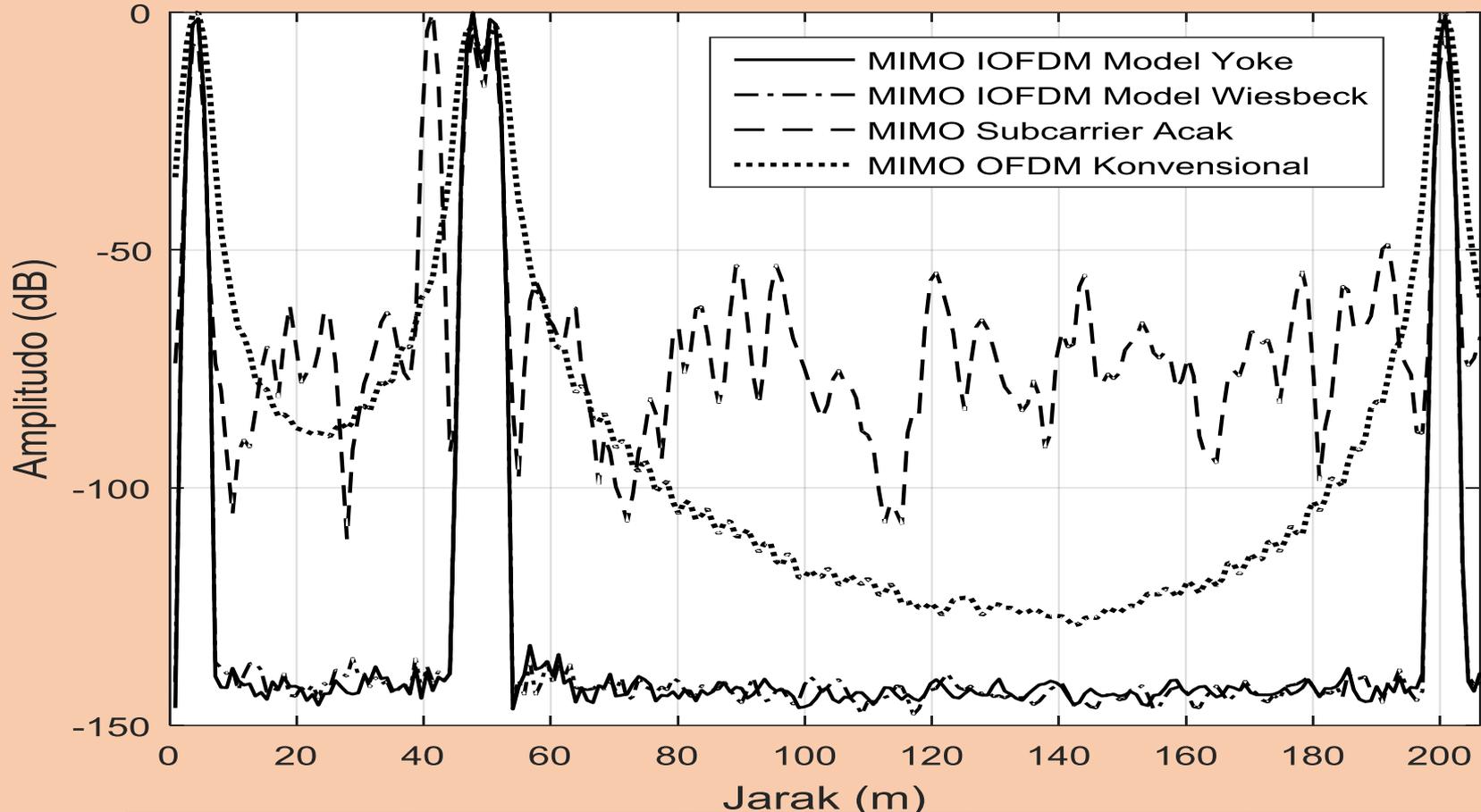
Deteksi Kecepatan



	Konvensional	Wiesbeck	Yoke	Acak
Resolusi Kec.	2.3m/s	2.3m/s	2.3m/s	2.3m/s
Rata2 error	0.22m/s	0.2m/s	0.2m/s	0.2m/s

Analisis MIMO OFDM

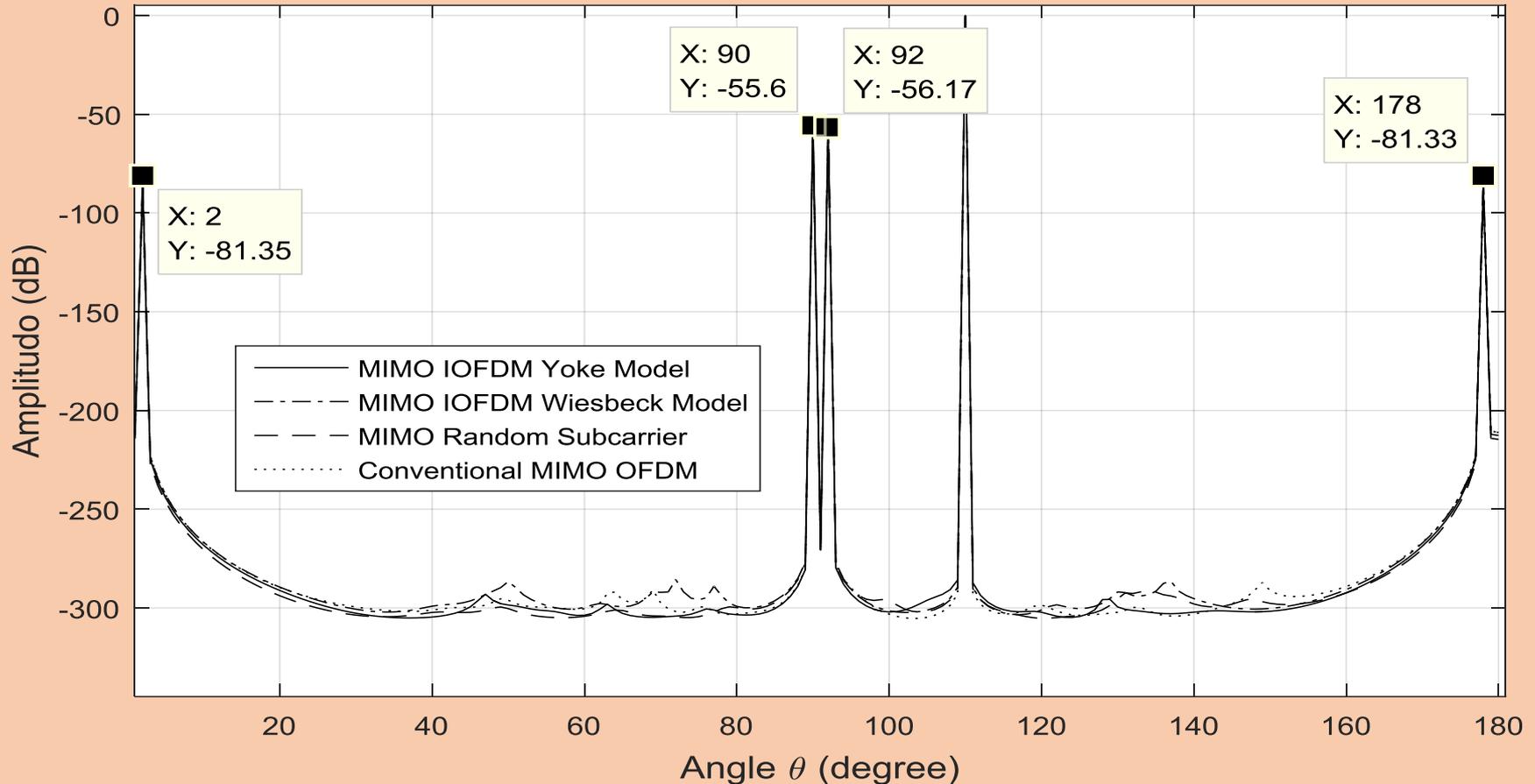
Deteksi Jarak



	Konvensional	Wiesbeck	Yoke	Acak
Resolusi Jarak	2.9m	2.8m	2.9m	2.9m
Rata2 error	0.93m	0.91m	0.91m	0.91m

Analisis MIMO OFDM

Deteksi DoA Menggunakan Algoritma MUSIC

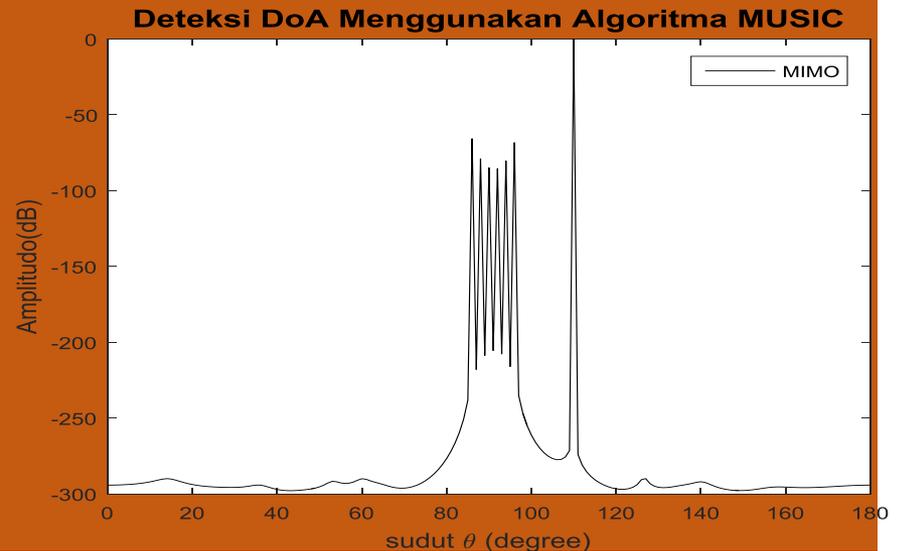
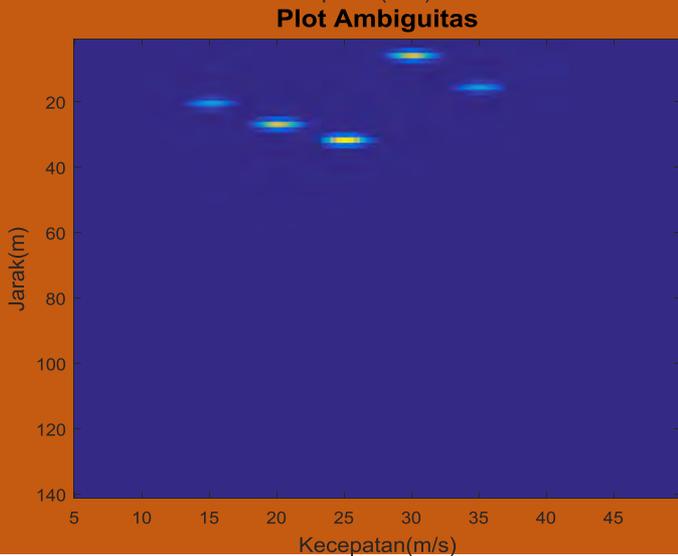
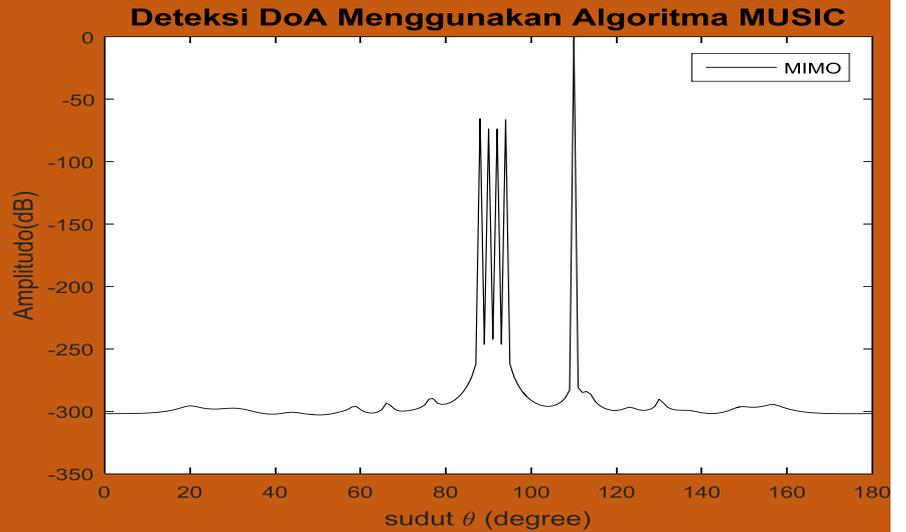
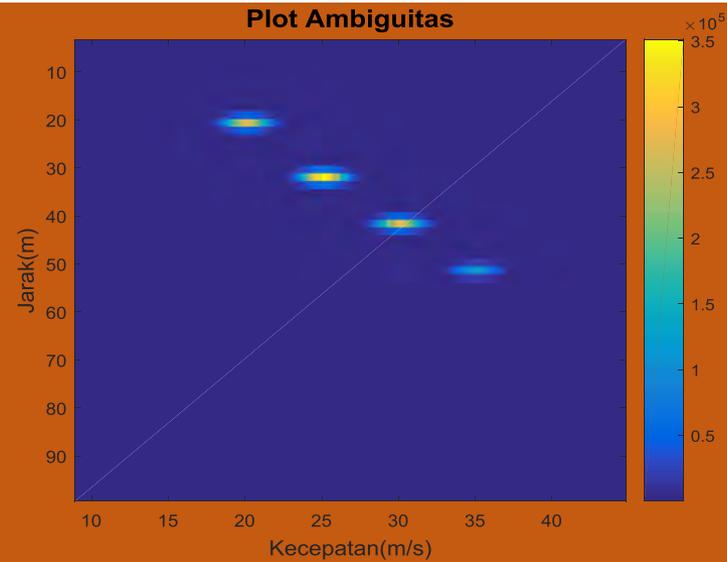


	Konvensional	Wiesbeck	Yoke	Acak
Resolusi Sudut	2°	2°	2°	2°
Rata2 error	0°	0°	0°	0°

Analisis Interferensi

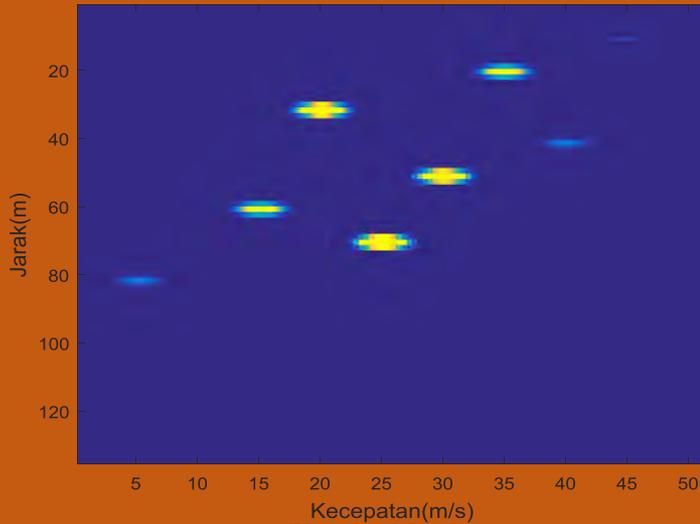
	Kenaikan <i>Side Lobe Level</i> (dB)							
	Konvensional		Wiesbeck		Yoke		Acak	
	Jarak	Kec.	Jarak	Kec.	Jarak	Kec.	Jarak	Kec.
Kec. 5m/s ke Kec. 50m/s	11.3 dB	23.9 dB	60.59 dB	66.5 dB	66.96 dB	68.66 dB	5.36 dB	11.5 dB

Deteksi Radar Model Wiesbeck

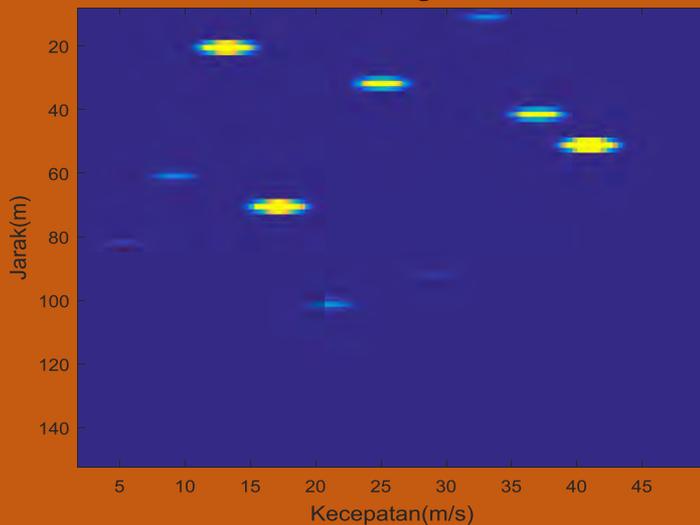


Deteksi Radar Model Wiesbeck

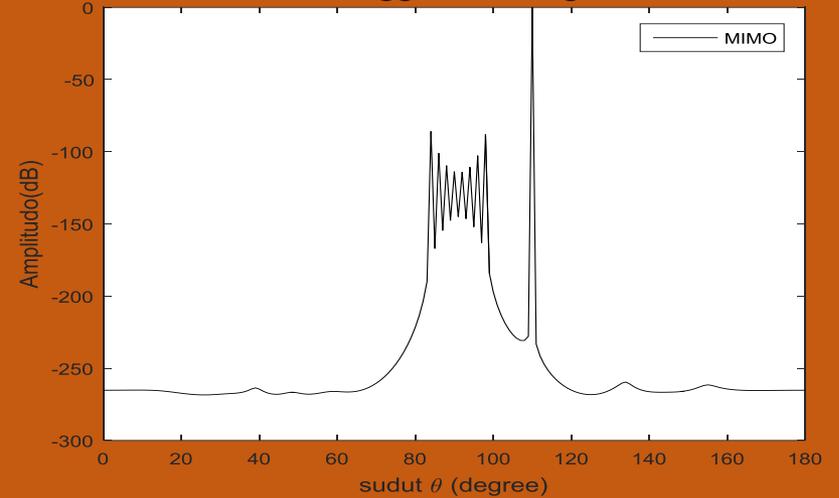
Plot Ambiguitas



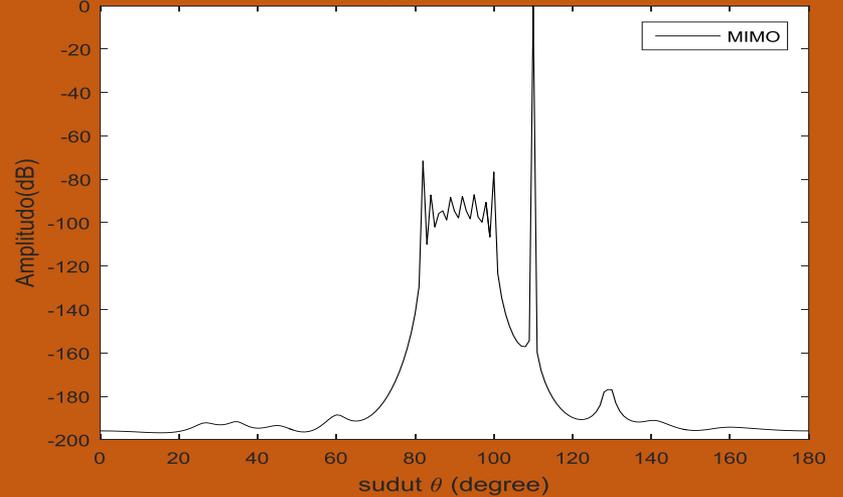
Plot Ambiguitas



Deteksi DoA Menggunakan Algoritma MUSIC

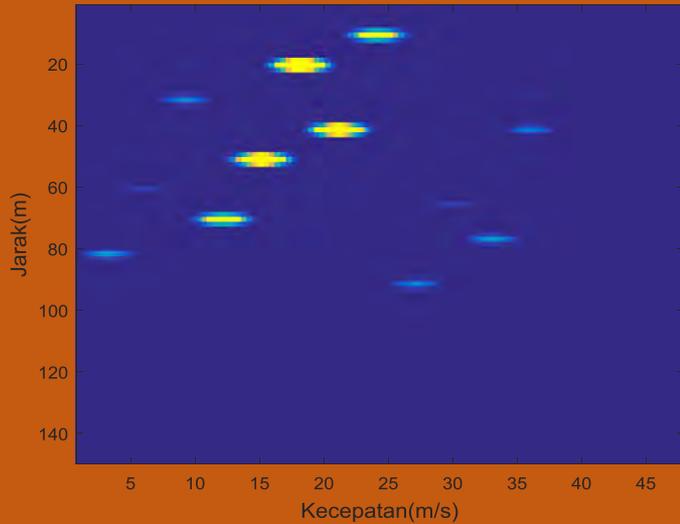


Deteksi DoA Menggunakan Algoritma MUSIC

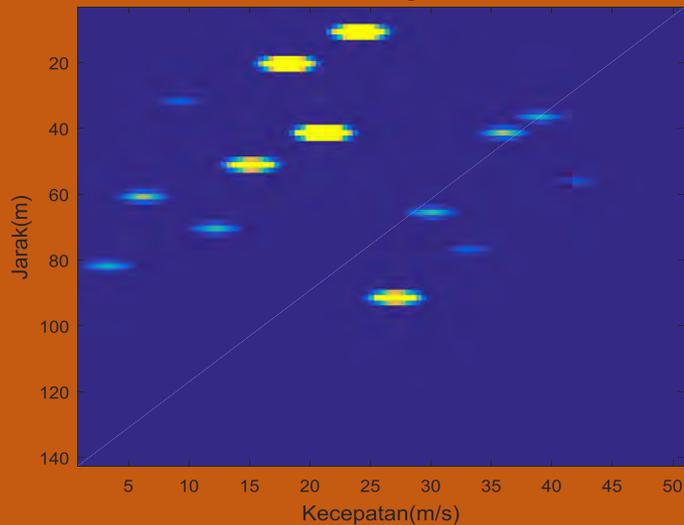


Deteksi Radar Model Wiesbeck

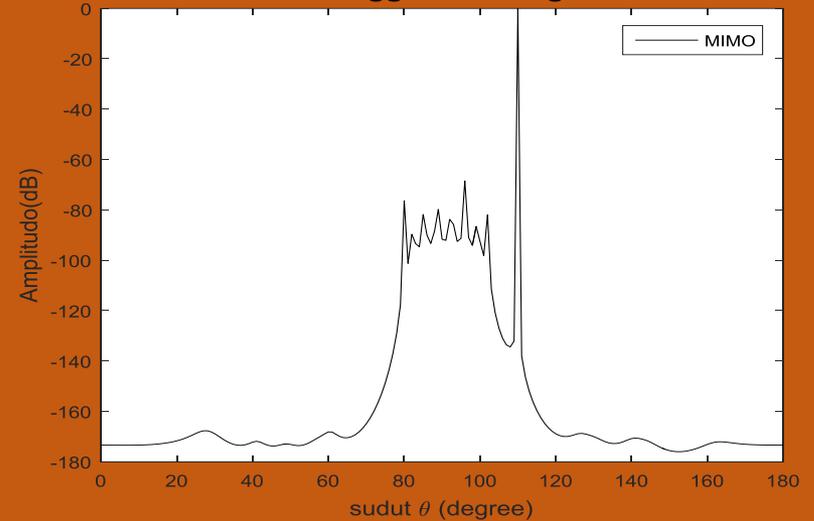
Plot Ambiguitas



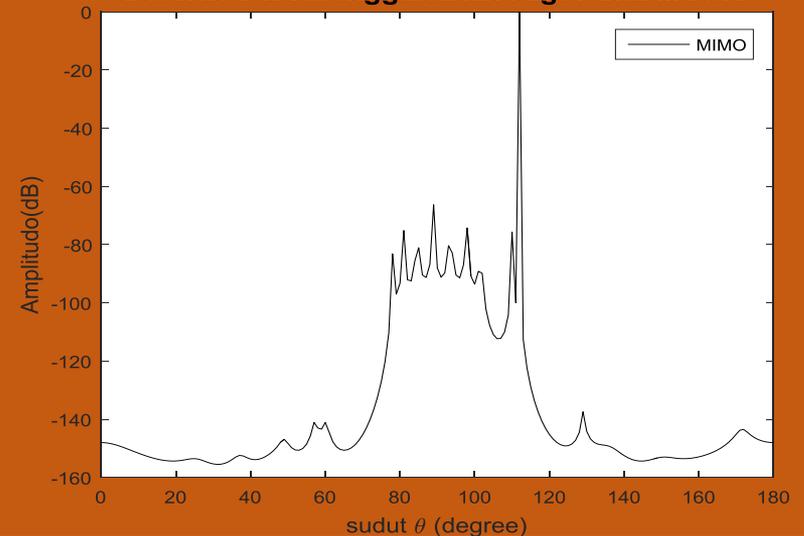
Plot Ambiguitas



Deteksi DoA Menggunakan Algoritma MUSIC

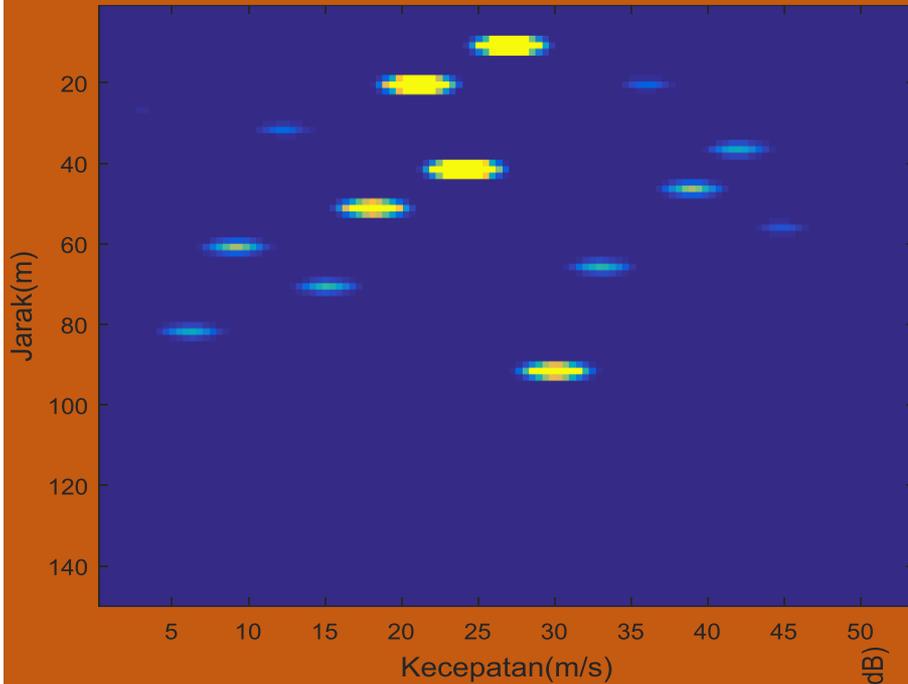


Deteksi DoA Menggunakan Algoritma MUSIC

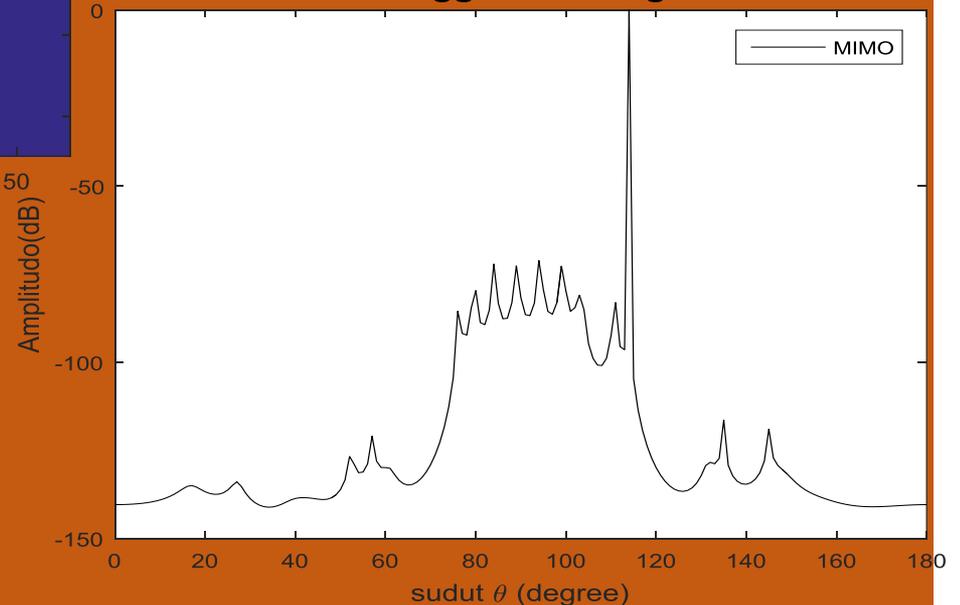


Deteksi Radar Model Wiesbeck

Plot Ambiguitas

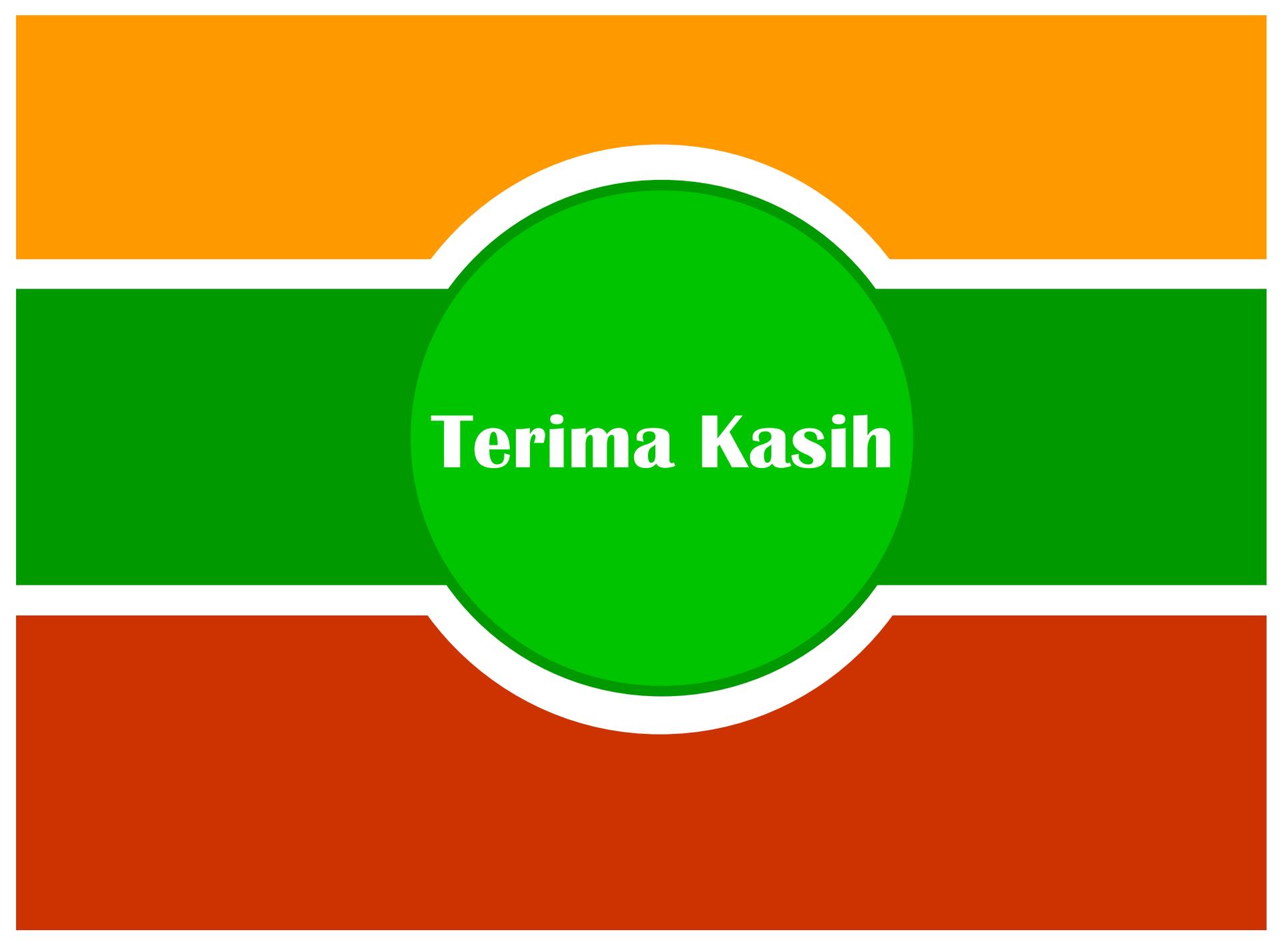


Deteksi DoA Menggunakan Algoritma MUSIC



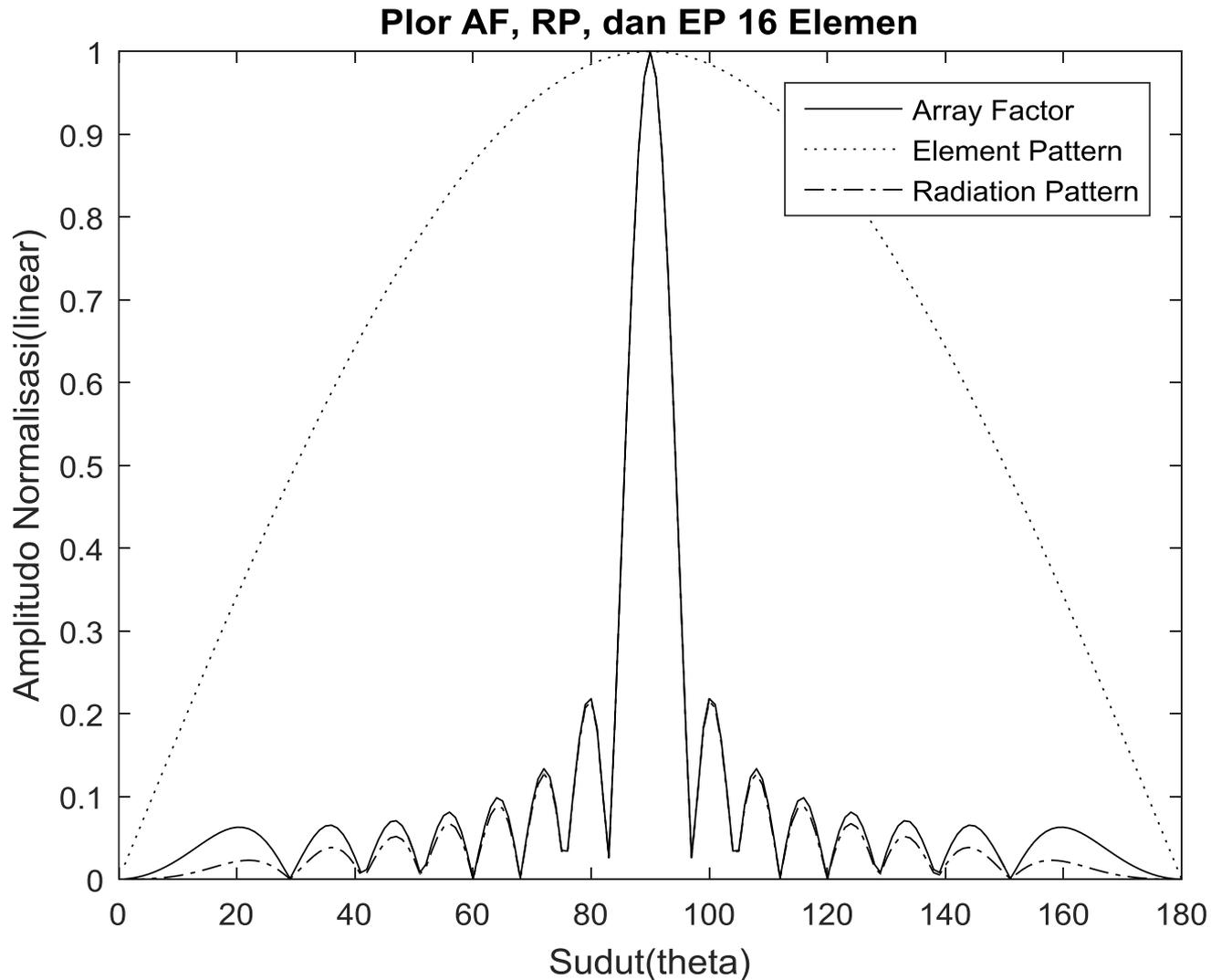
Kesimpulan

- Resolusi Jarak dari keempat model radar MIMO adalah sama yaitu 2.3m
- Resolusi kecepatan MIMO-IOFDM Model Wiesbeck adalah 2.8m/s, sedangkan resolusi kecepatan ketiga model lainnya adalah sama yaitu 2.9m/s
- Resolusi sudut keempat model MIMO adalah sama yaitu 2°
- MIMO-OFDM Acak paling tahan terhadap interferensi
- MIMO-IOFDM model Wiesbeck unggul dari beberapa aspek jika dibanding ketiga model yang lain, meskipun setiap model memiliki kelemahan dan kelebihan masing-masing.

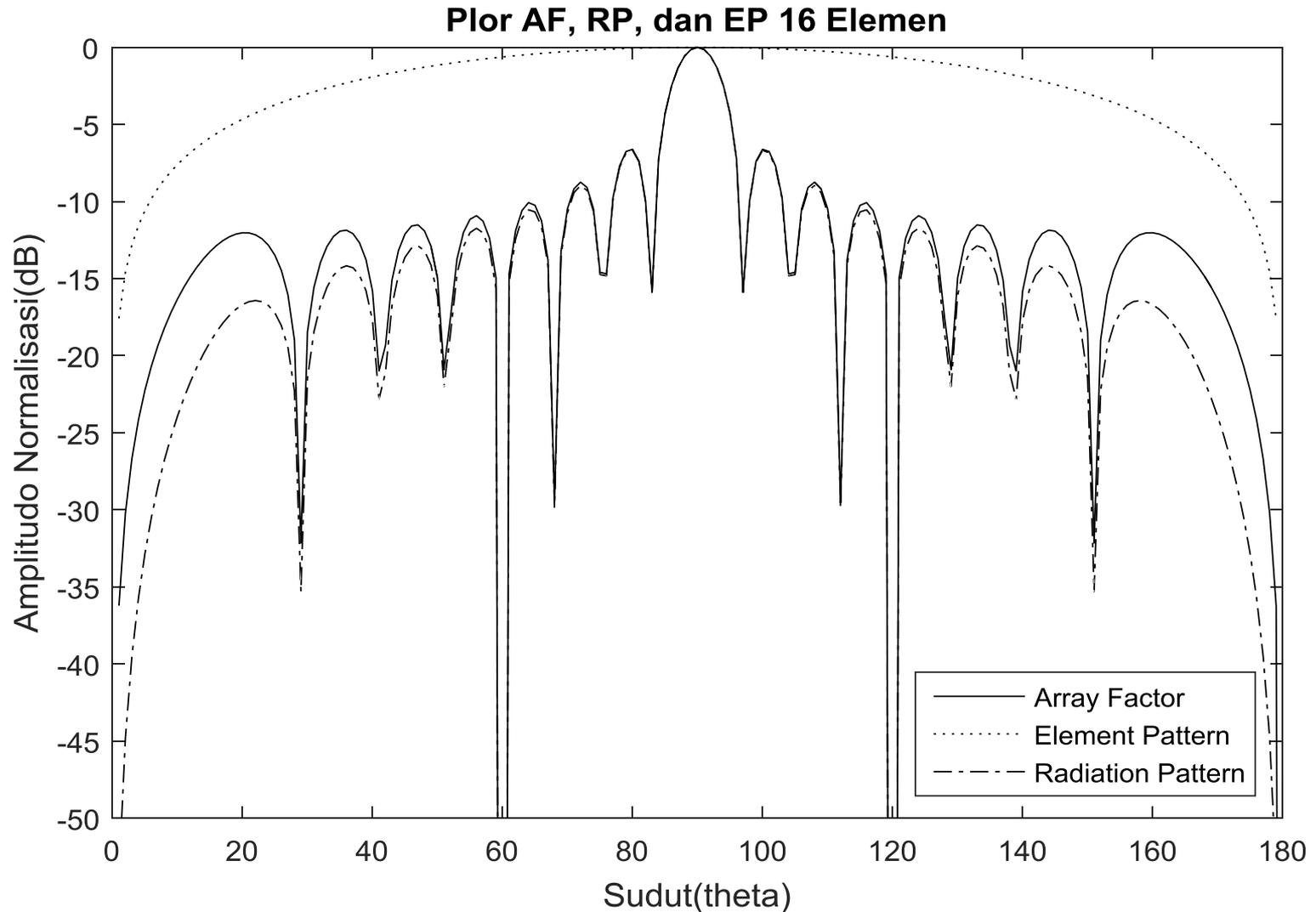


Terima Kasih

Plot AF, RP, dan EP 16 elemen

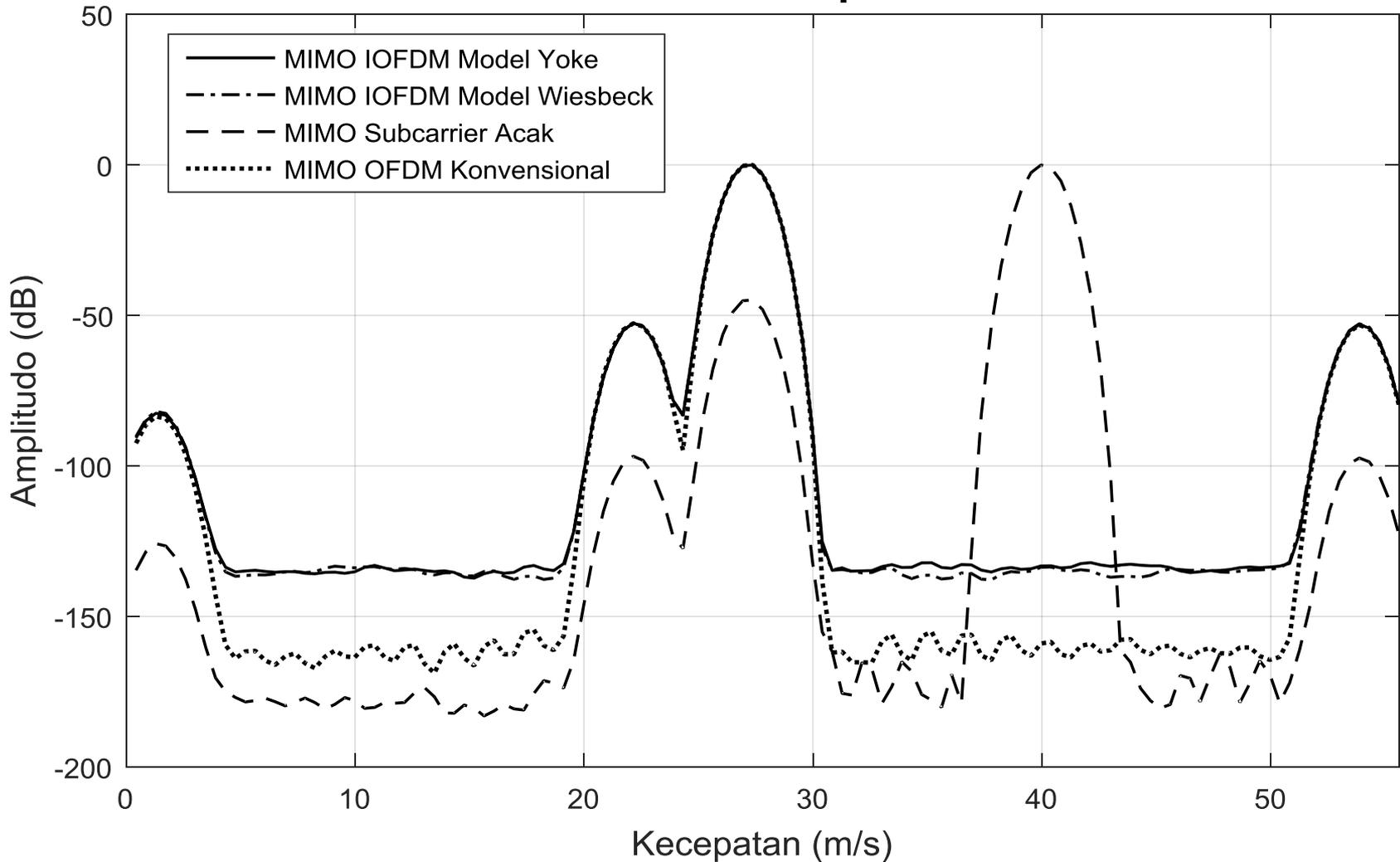


Plot AF, RP, dan EP 16 elemen

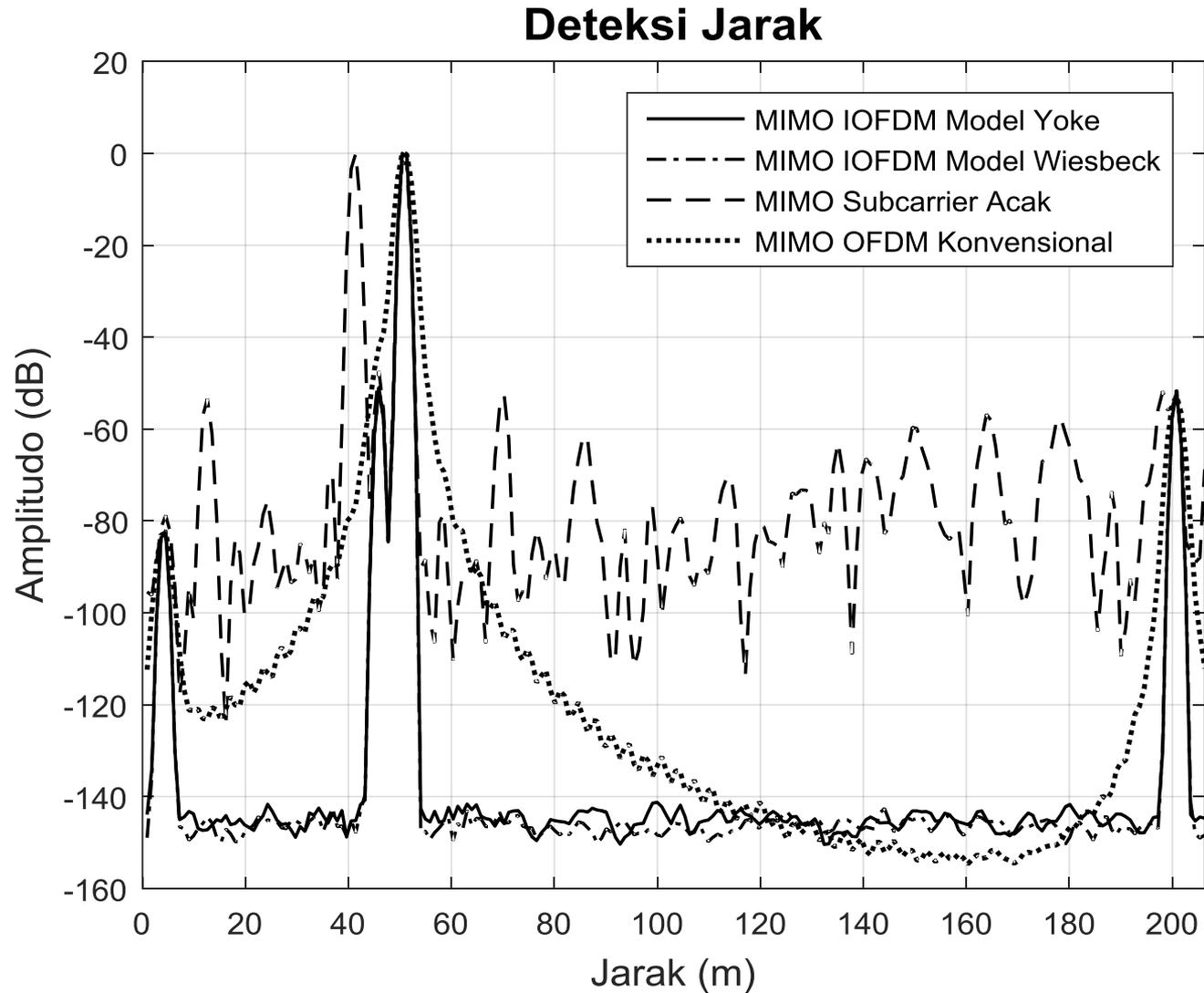


Plot 4 Model Deteksi Kecepatan

Deteksi Kecepatan

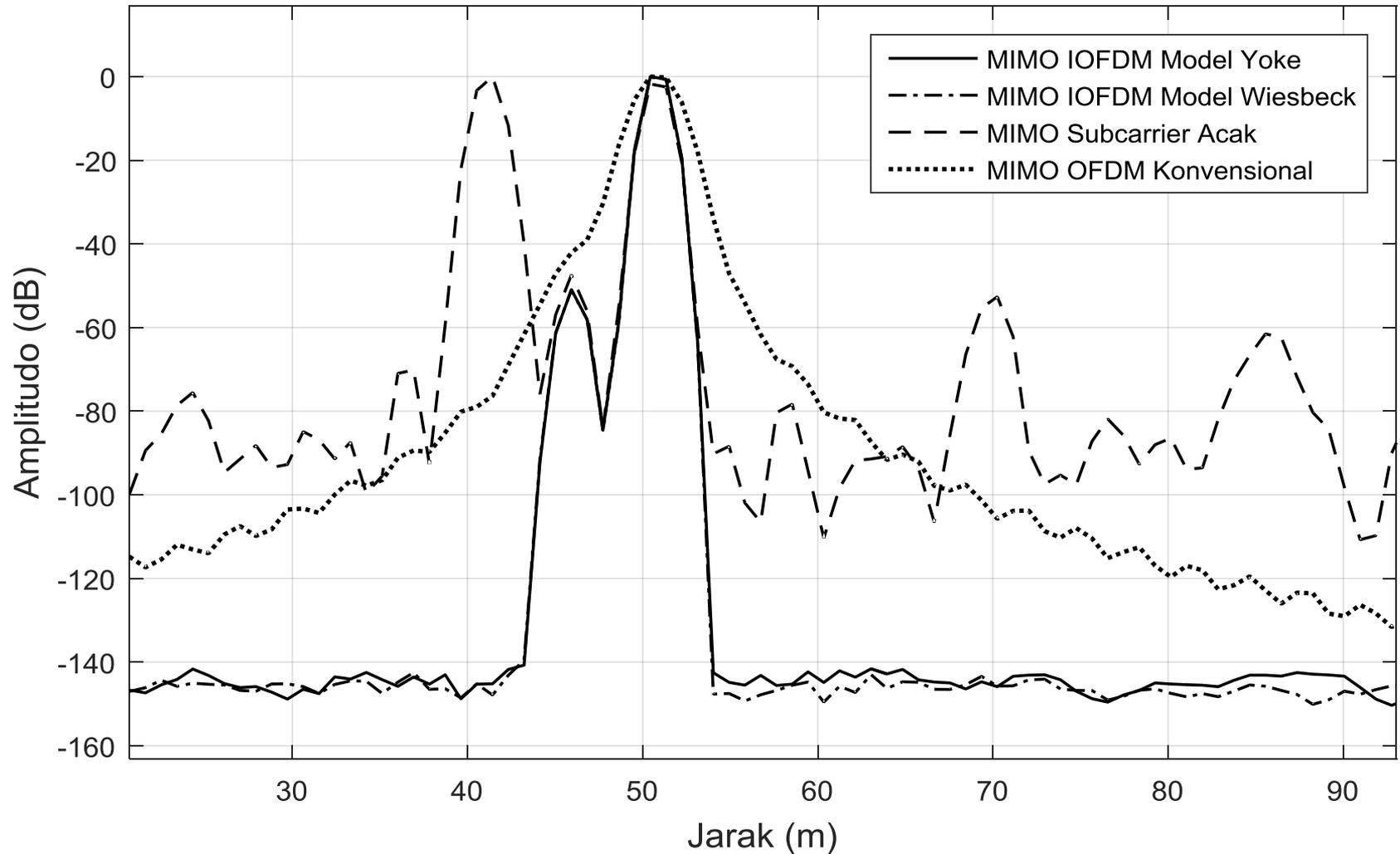


Plot 4 Model Deteksi Jarak



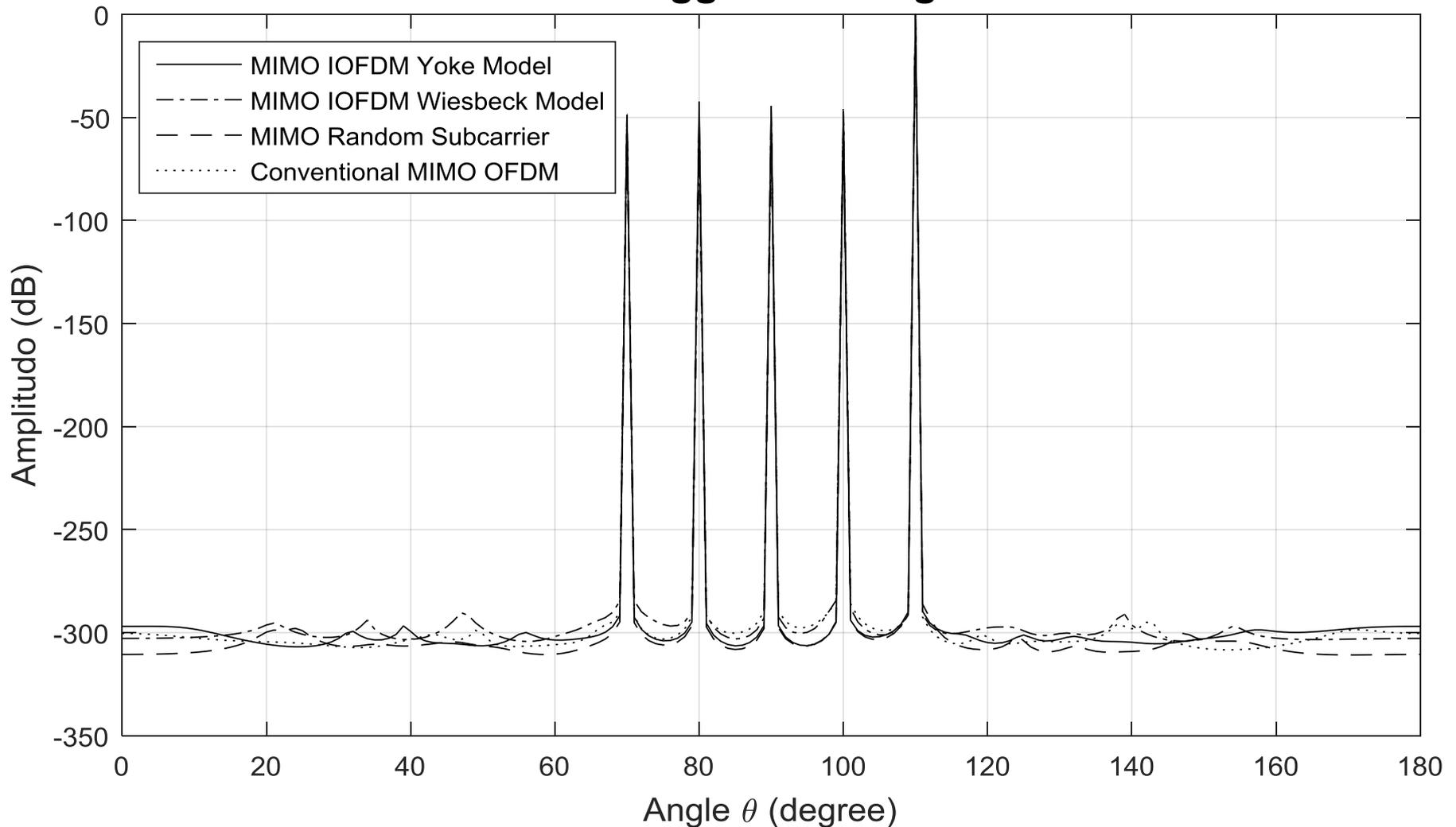
Plot 4 Model Deteksi Jarak

Deteksi Jarak



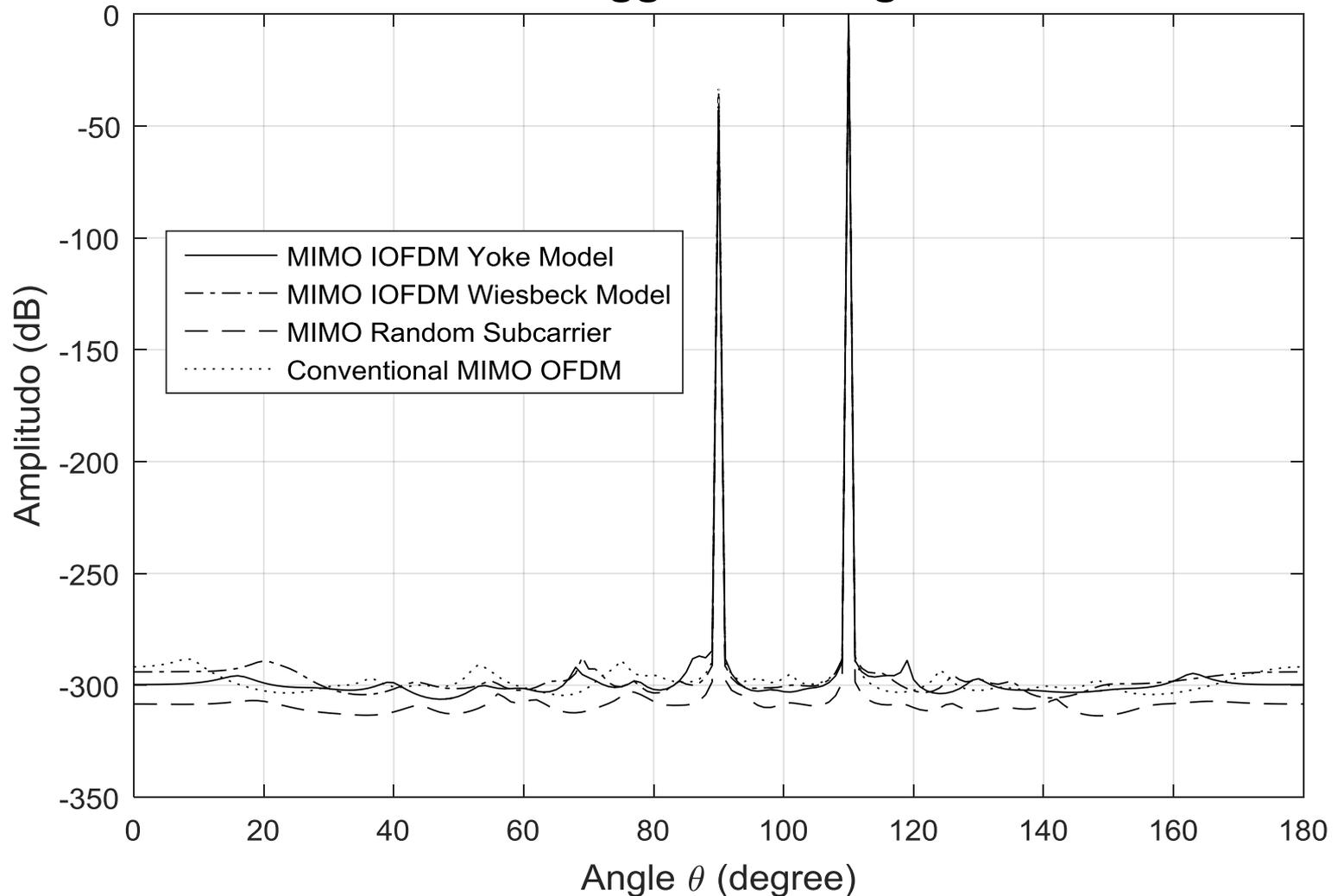
Plot 4 Model Deteksi DoA

Deteksi DoA Menggunakan Algoritma MUSIC

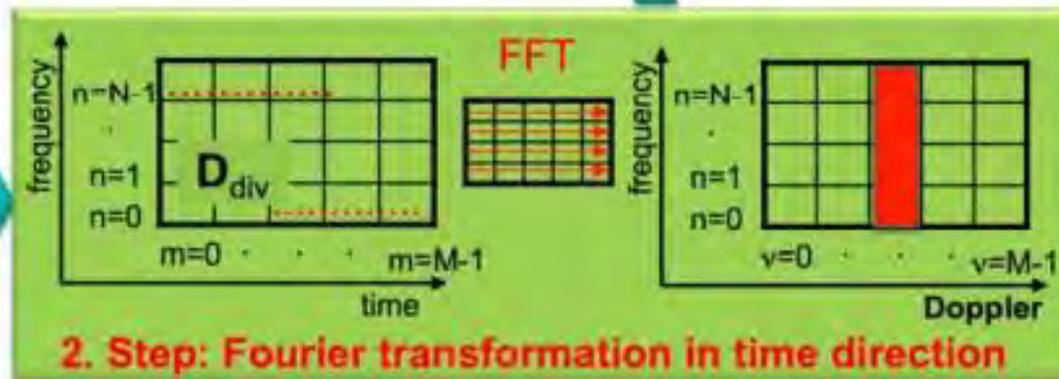
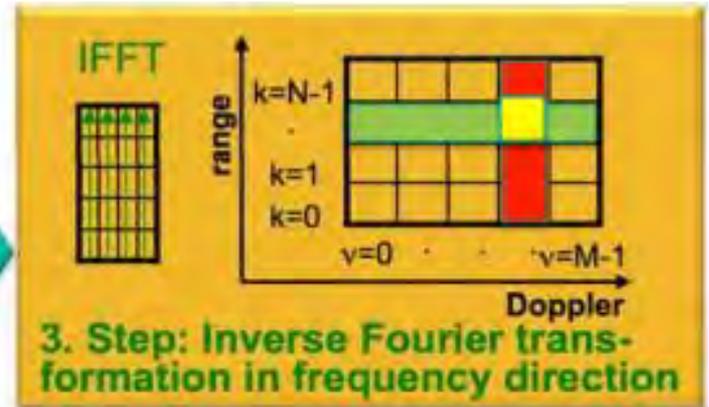
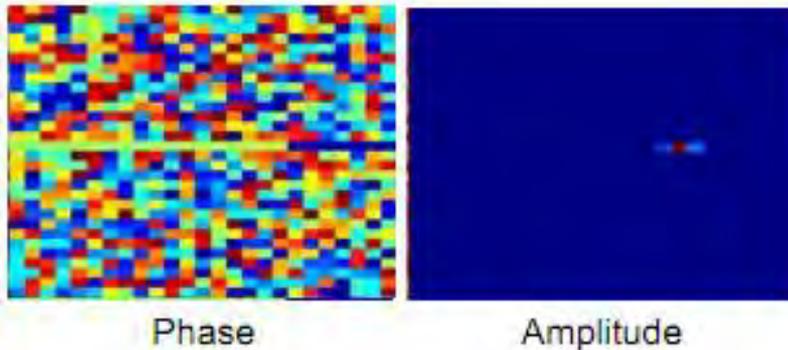


Plot 4 Model Deteksi DoA (sudut 90)

Deteksi DoA Menggunakan Algoritma MUSIC



Konsep Periodogram

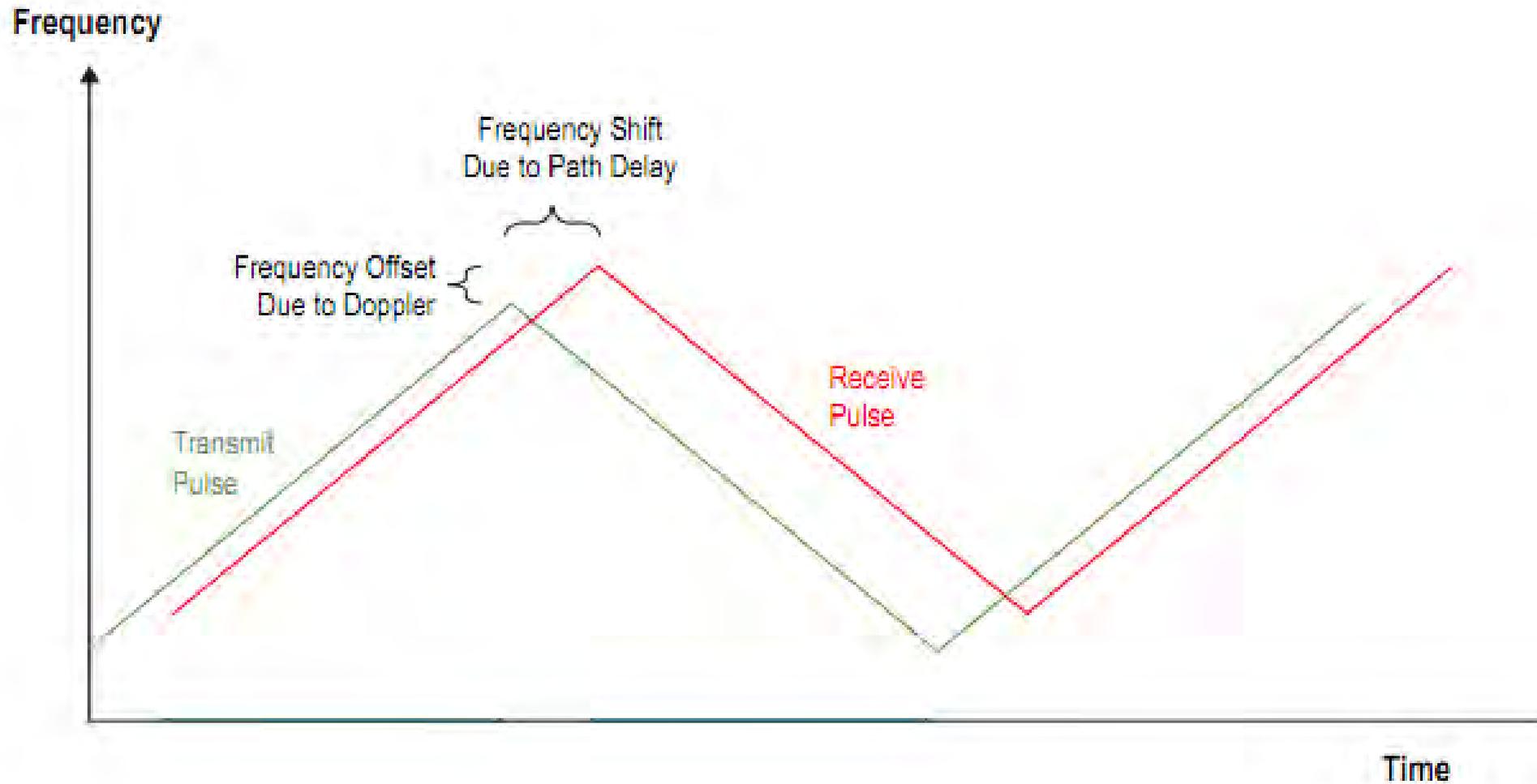


1. Step:
complex division
of symbols

$$D_{div}(m,n) = \frac{D_{Rx}(m,n)}{D_{Tx}(m,n)}$$

Processing gain $G_P = N_c \cdot M_{sym}$

Konsep Periodogram



Rumus

$$R = \frac{cT_R}{2}$$

$$\Delta R = \frac{c}{2 N c \Delta f}$$

$$R_{unamb} = \frac{cT_p}{2}$$

$$V_{max} = \frac{\Delta f \lambda}{2}$$

$$V = \frac{c f_D}{2 f}$$

$$\Delta V = \frac{\lambda}{2 T_{OFDM} \Delta f}$$

$$V_{unamb} = \frac{c}{2 f T}$$

$$AF = \sum_{n=0}^{N-1} A_n e^{jn(\beta d \cos(\theta) + \alpha)}$$

$$f_D = \frac{2 v}{\lambda}$$

$$t_d = \frac{c/f}{2d((MtMr) - 1) \cos(\theta)}$$

$$R_{max} = \frac{c}{2 \Delta f}$$

$$f(\theta, \phi) = \sqrt{1 - \sin^2 \theta \cos^2 \phi}$$

Transformasi Fourier

- Expresses a (real) periodic function $x(t)$ as a sum of trigonometric series ($-L < t < L$)

$$x(t) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty} \left(a_n \cos \frac{\pi n}{L}t + b_n \sin \frac{\pi n}{L}t \right)$$

- Coefficients can be computed by

$$a_n = \frac{1}{L} \int_{-L}^L x(t) \cos \frac{\pi n}{L}t dt$$

$$b_n = \frac{1}{L} \int_{-L}^L x(t) \sin \frac{\pi n}{L}t dt$$

- Generalization of Fourier Series for infinite domain

$$x(t) = \int_{-\infty}^{\infty} \mathcal{F}(f) e^{-2\pi i f t} df$$

$$\mathcal{F}(f) = \int_{-\infty}^{\infty} x(t) e^{2\pi i f t} dt$$

- Can represent continuous, aperiodic signals
- Continuous frequency spectrum

- Generalized to complex-valued functions as

$$x(t) = \sum_{n=-\infty}^{\infty} c_n e^{i \frac{\pi n}{L}t}$$

$$c_n = \frac{1}{2L} \int_{-L}^L x(t) e^{-i \frac{\pi n}{L}t} dt$$

- If the signal $X(k)$ is periodic, band-limited and sampled at Nyquist frequency or higher, the DFT represents the CFT exactly¹⁴

$$A(r) = \sum_{k=0}^{N-1} X(k) \mathbf{W}_N^{rk}$$

where $\mathbf{W}_N = e^{-\frac{2\pi i}{N}}$ and $r = 0, 1, \dots, N-1$

- The inverse transform:

$$X(j) = \frac{1}{N} \sum_{k=0}^{N-1} A(k) \mathbf{W}_N^{-jk}$$

