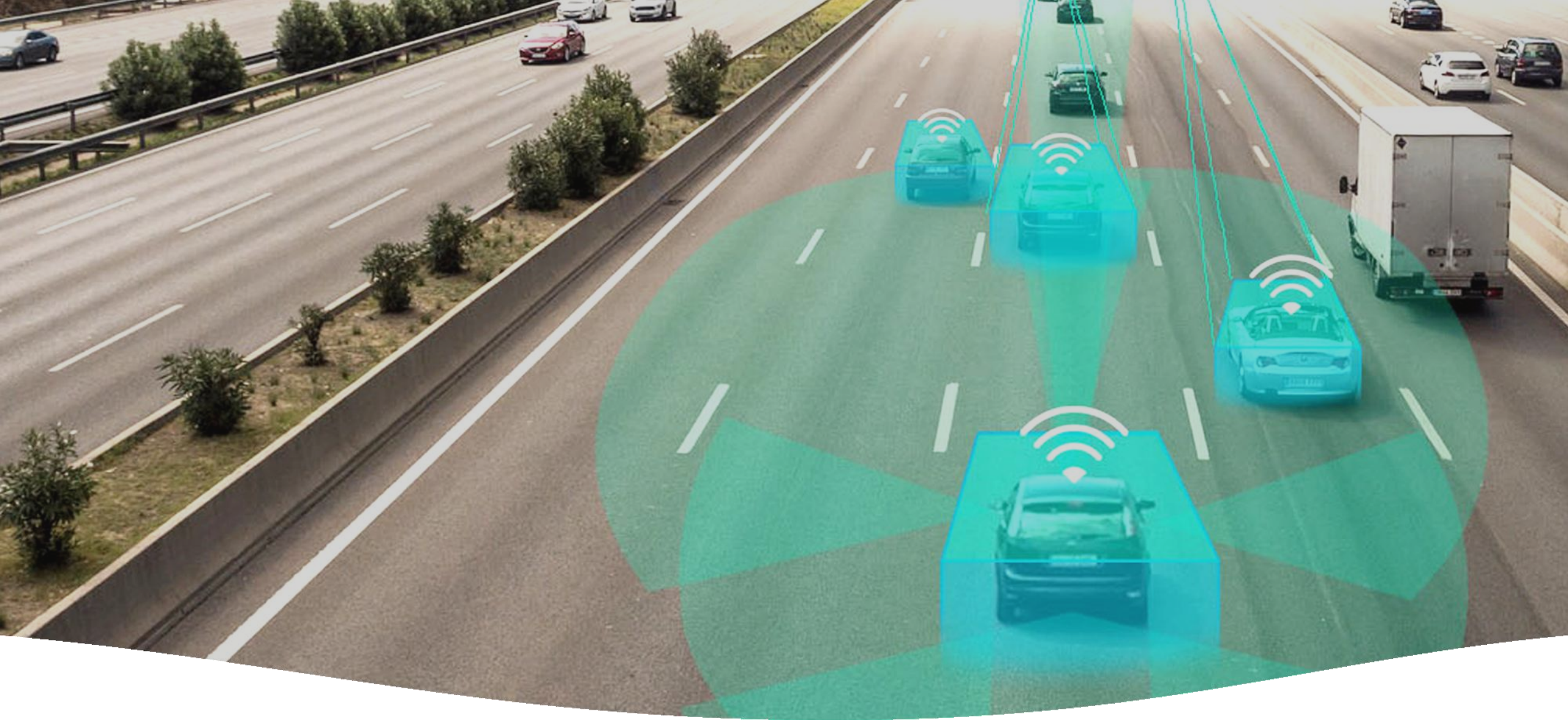


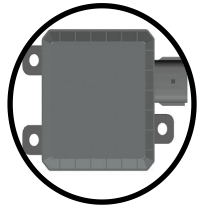
自动驾驶毫米波雷达

关键技术和设计要点

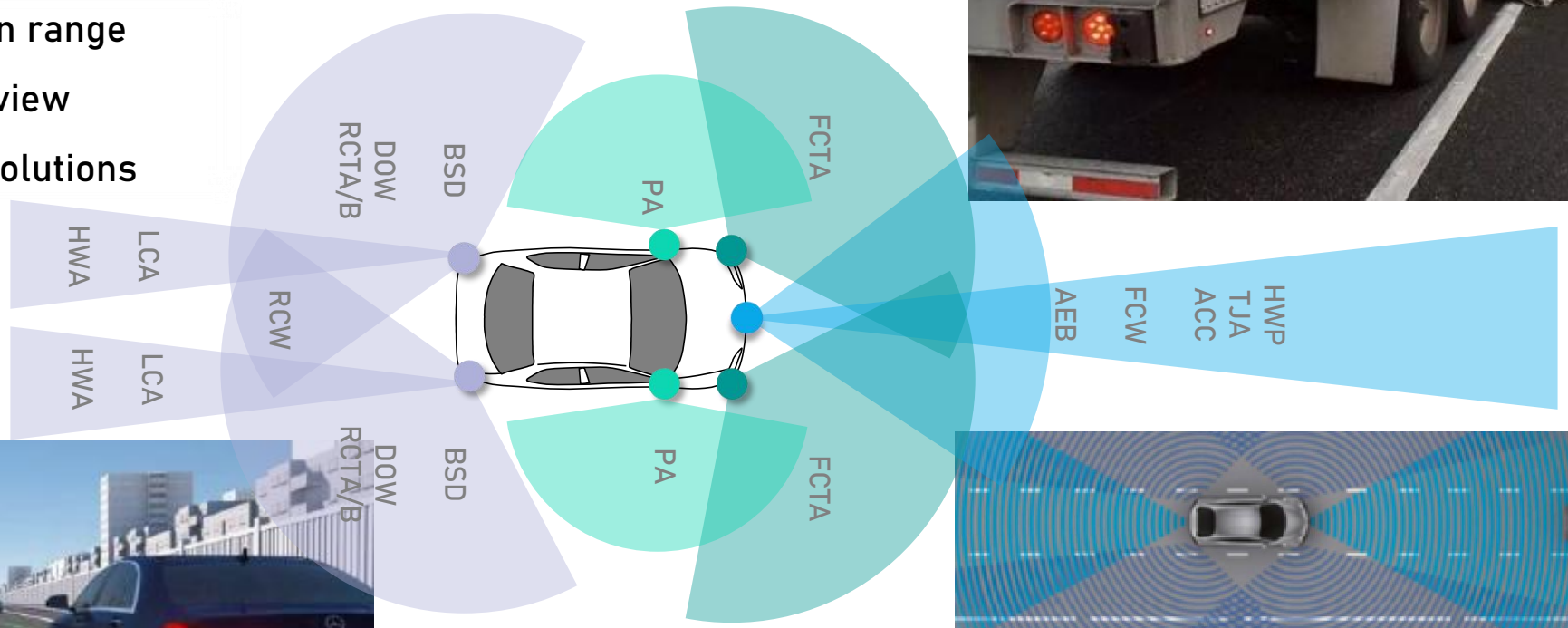
买剑春
雷达系统工程师

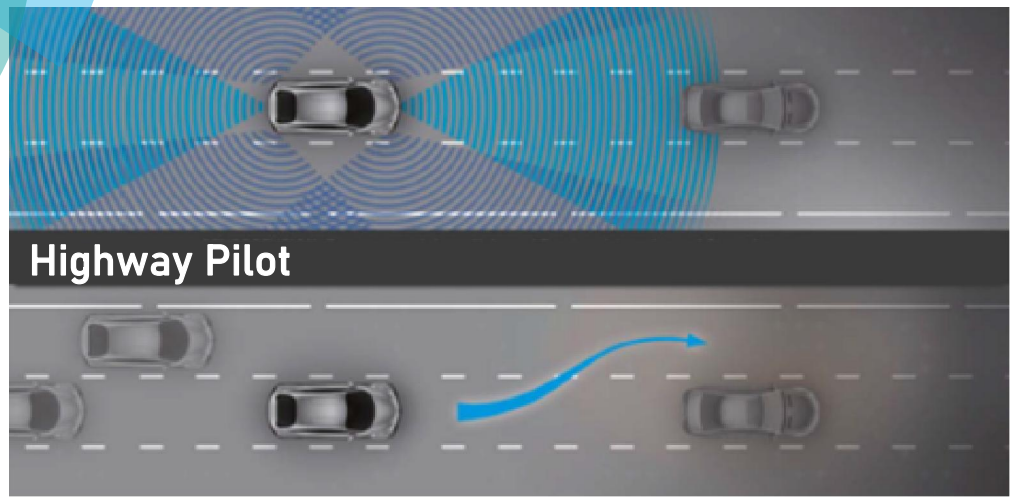
HAWKEYE
隼眼科技

车载毫米波雷达发展趋势
Trends of Automotive Radar



- Detection range
- Field of view
- High resolutions





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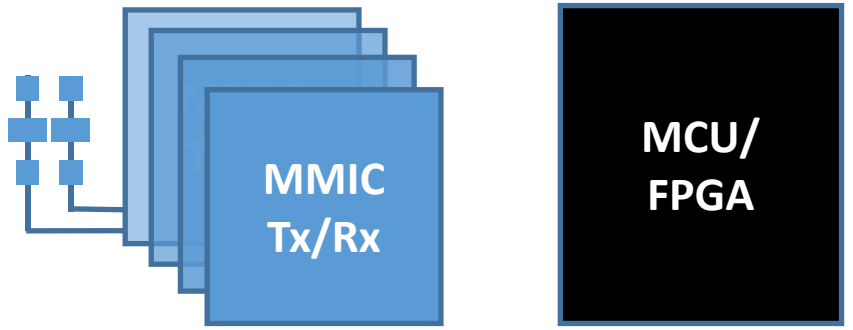
毫米波雷达硬件演进
Radar HW Evolution

CURRENT

FUTURE



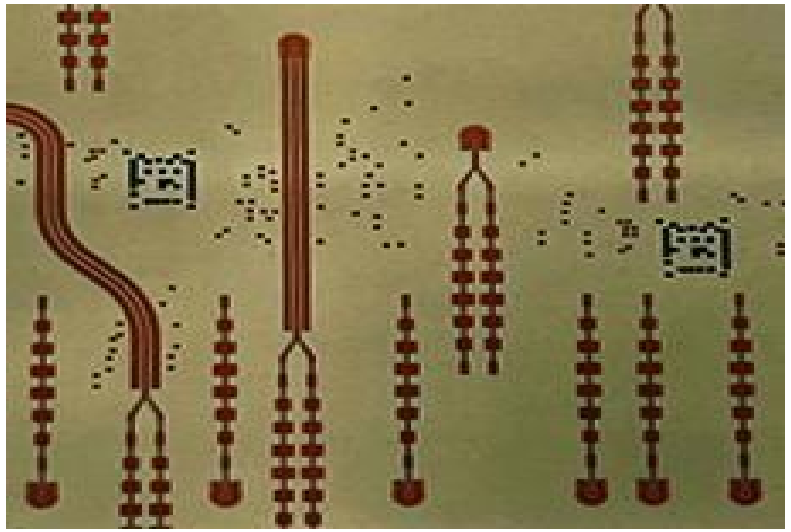
BOM cost	**LOW**	**HIGH**
Channel number	**.../2T4R/3T4R**	**3T4R/4T4R x MMIC number**
Azi. resolution	**LOW / MEDIUM**	**HIGH**
Ele. resolution	**NONE / LOW**	**MEDIUM / HIGH**

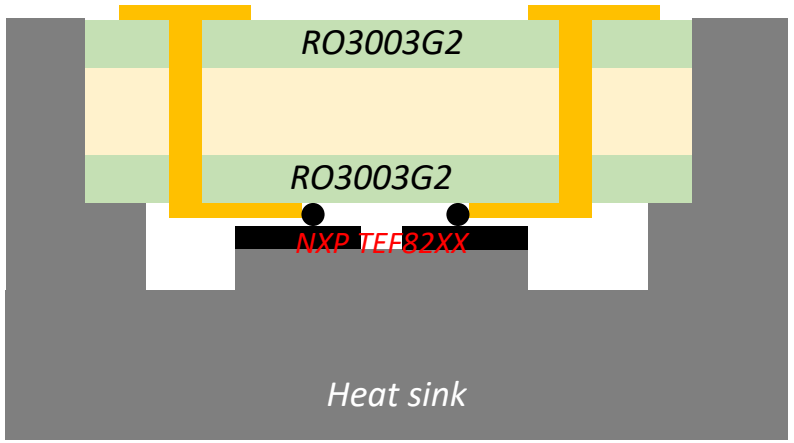
- 检测机动车，VRU
- 车道级探测精度
- NCAP（AEB、BSD等）

雷达需要更强的探测威力和更高的角度分辨

- 360°感知（Cocoon Radar）
- 方位、俯仰高精度、高分辨
- 弱目标（路障、路沿）探测
- 自动变道、自动泊车、环境地图等

背馈天线
Back-fed Antenna

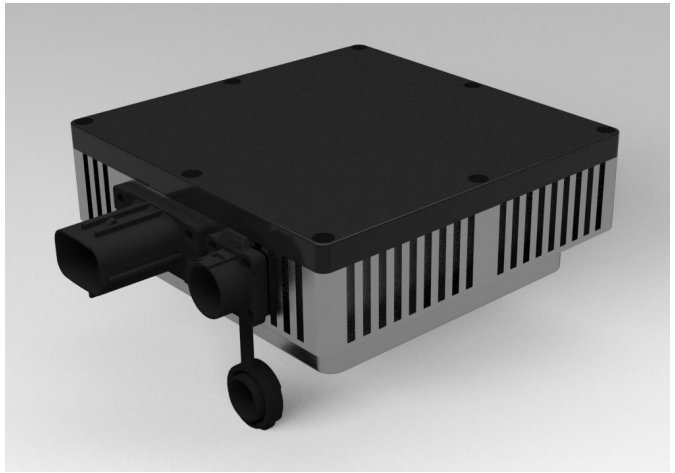




设计优势

- 灵活阵列布局，缩小雷达尺寸 **SIZE: 100x100x30 mm**
- 减小馈线损耗，提升雷达威力 **L_{sys}↓3dB，R_{max}↑20%**
- 减小馈线辐射，提升测角精度与感知灵敏度 **ε_{DOA}↑100%**
- 提高多维角度分辨率及稳健性

Automotive / Urban Traffic 4D Sensor

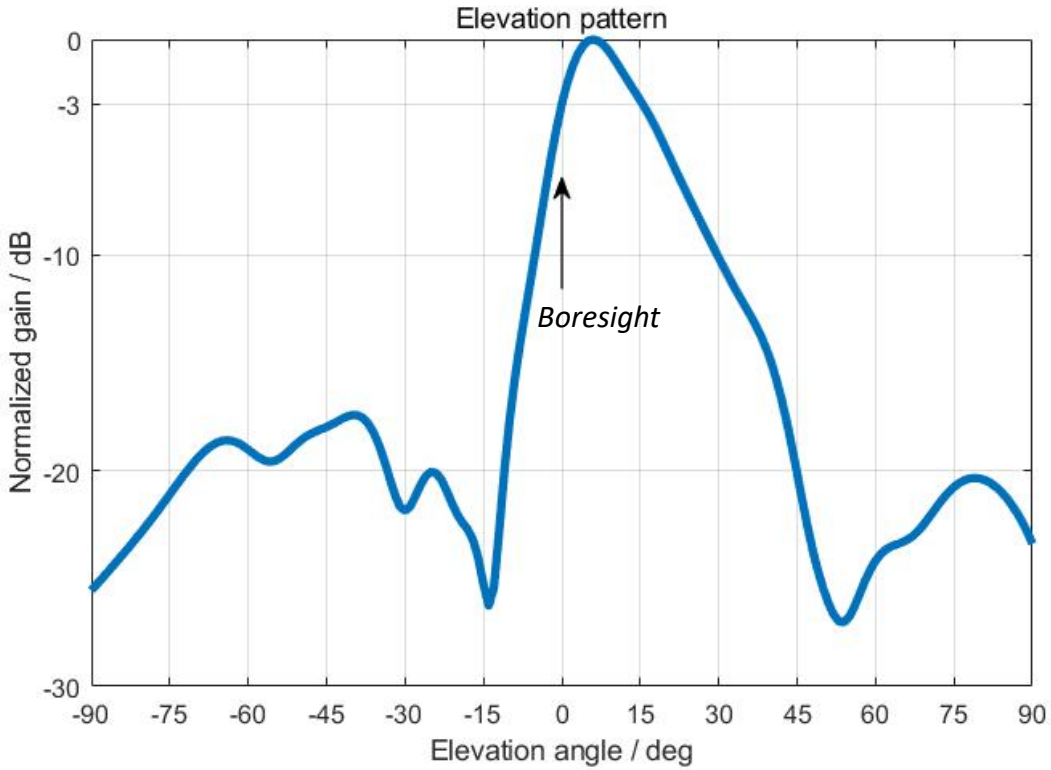


120 / 30 deg FoV(AZ/EL)	**1.6 / 3.5 deg** AZ/EL Resolution
0.1 deg AZ/EL Precision	**300 m** MAX Range

Auto calibraion (AZ/EL)	**Support**
Object classification	**Support**

波束赋形
Beamforming

车路协同&交通雷达应用



根据应用场景需求设计天线波束指向和形状

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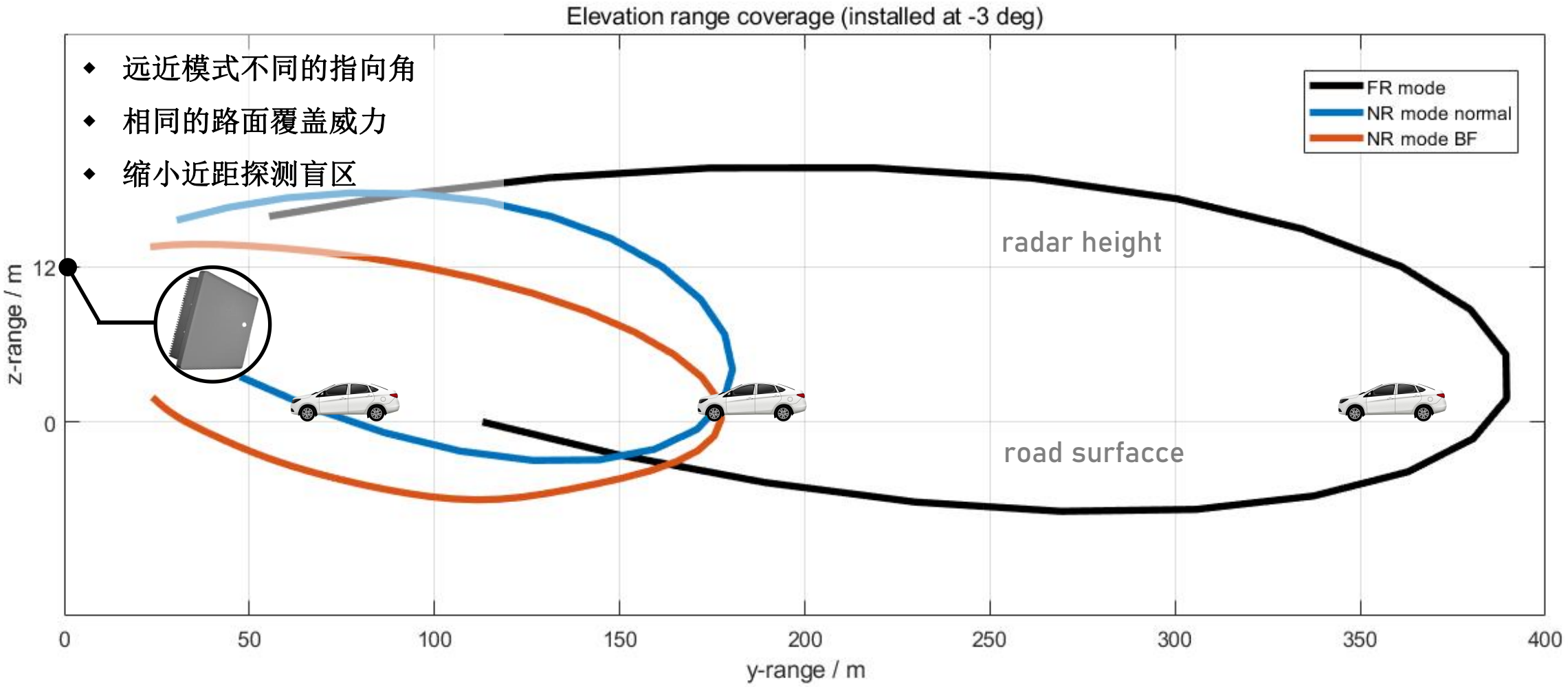
车路协同应用
VIC Scenario

- 远近模式不同的指向角
- 相同的路面覆盖威力
- 缩小近距探测盲区



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单芯片高分辨雷达
Single-chip High Resolution Radar

SRR Corner Sensor

150 / 30 deg
FoV(AZ/EL)

1.7 deg
AZ Resolution

0.2 / 0.5 deg
AZ/EL Precision

Elevation measurement	support
Detction Doppler range	+/-360 kph

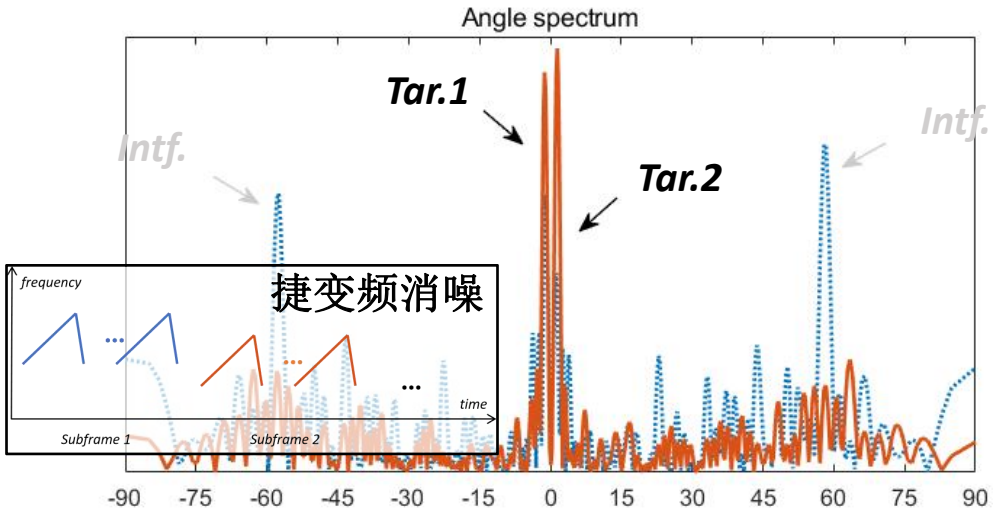
TEF82xx | S32R294 | NXP

FS84xx | TJA104x | TJA1101

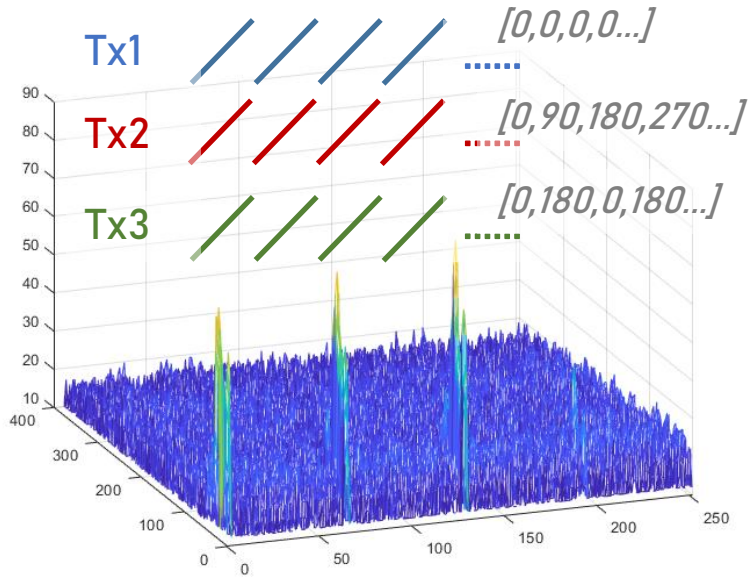
Key Tech

- Sparse MIMO array based on single-chip
- Agile Frequency
- DDMA
- SW super-resolution
- Doppler expansion
- De-Cluttering

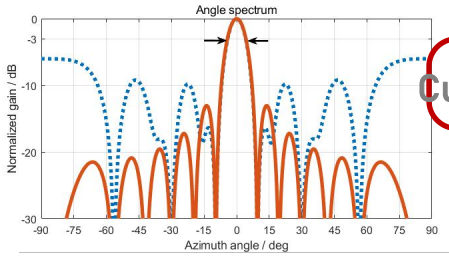
稀疏MIMO阵列信号处理
Sparse MIMO Array Signal Processing



Agile Frequency



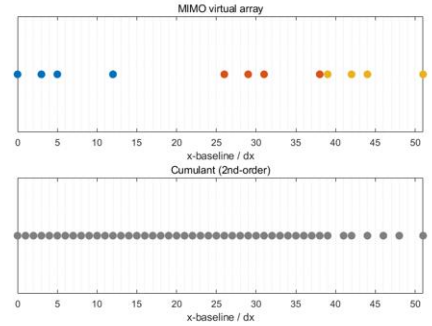
DDMA: Doppler Divsion Multiple Access

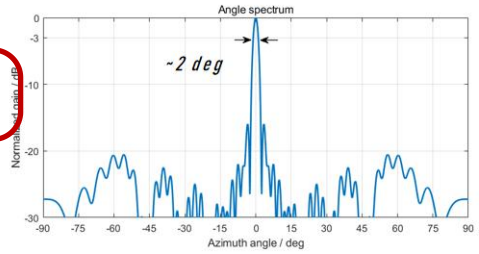


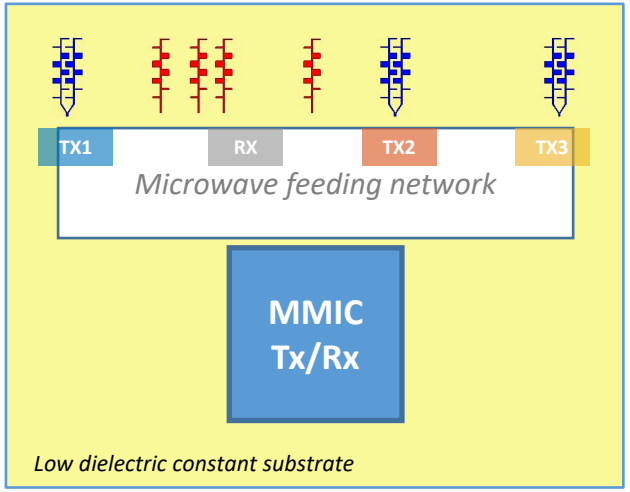
MIMO
2T3R

基线组间做差构建二阶累积量的虚拟域

Cumulant







稀疏MIMO阵列 & 高阶累积量DOA

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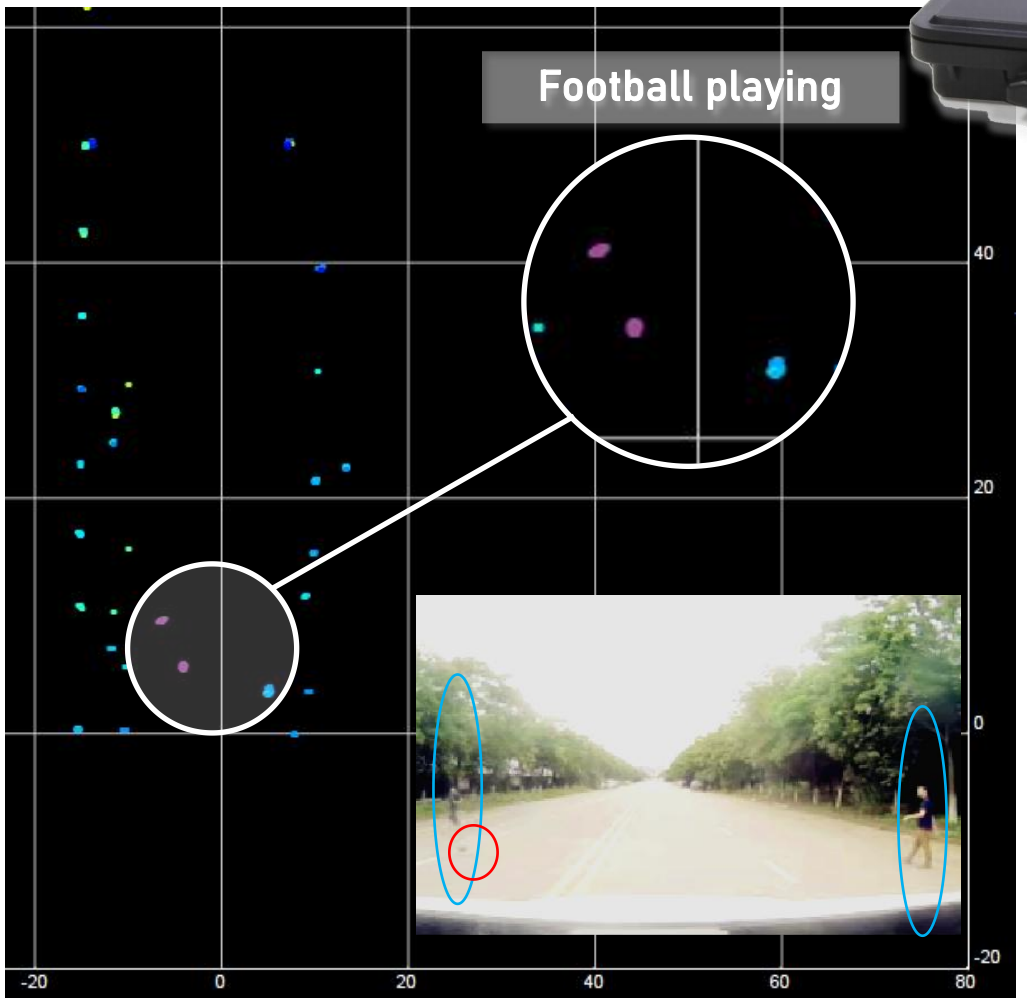
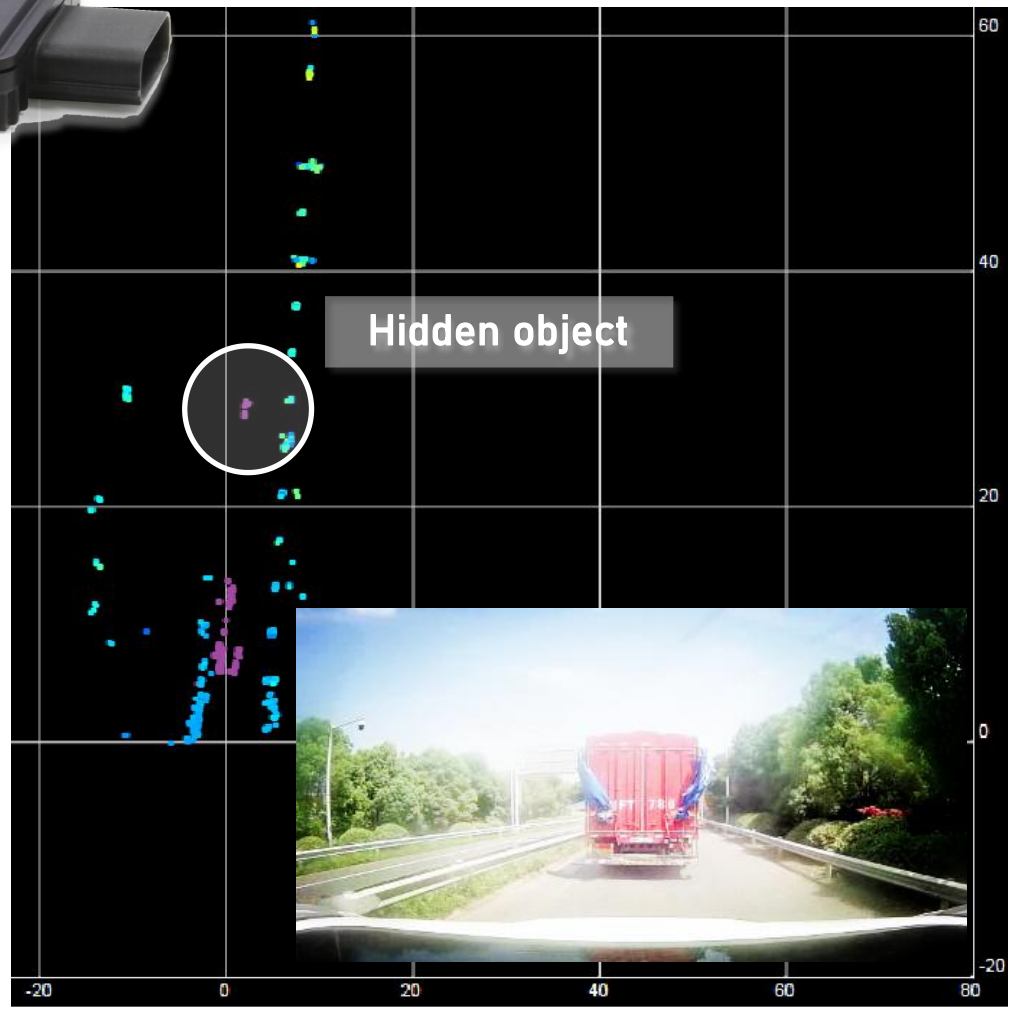
道路测试场景
Road Test Scenario





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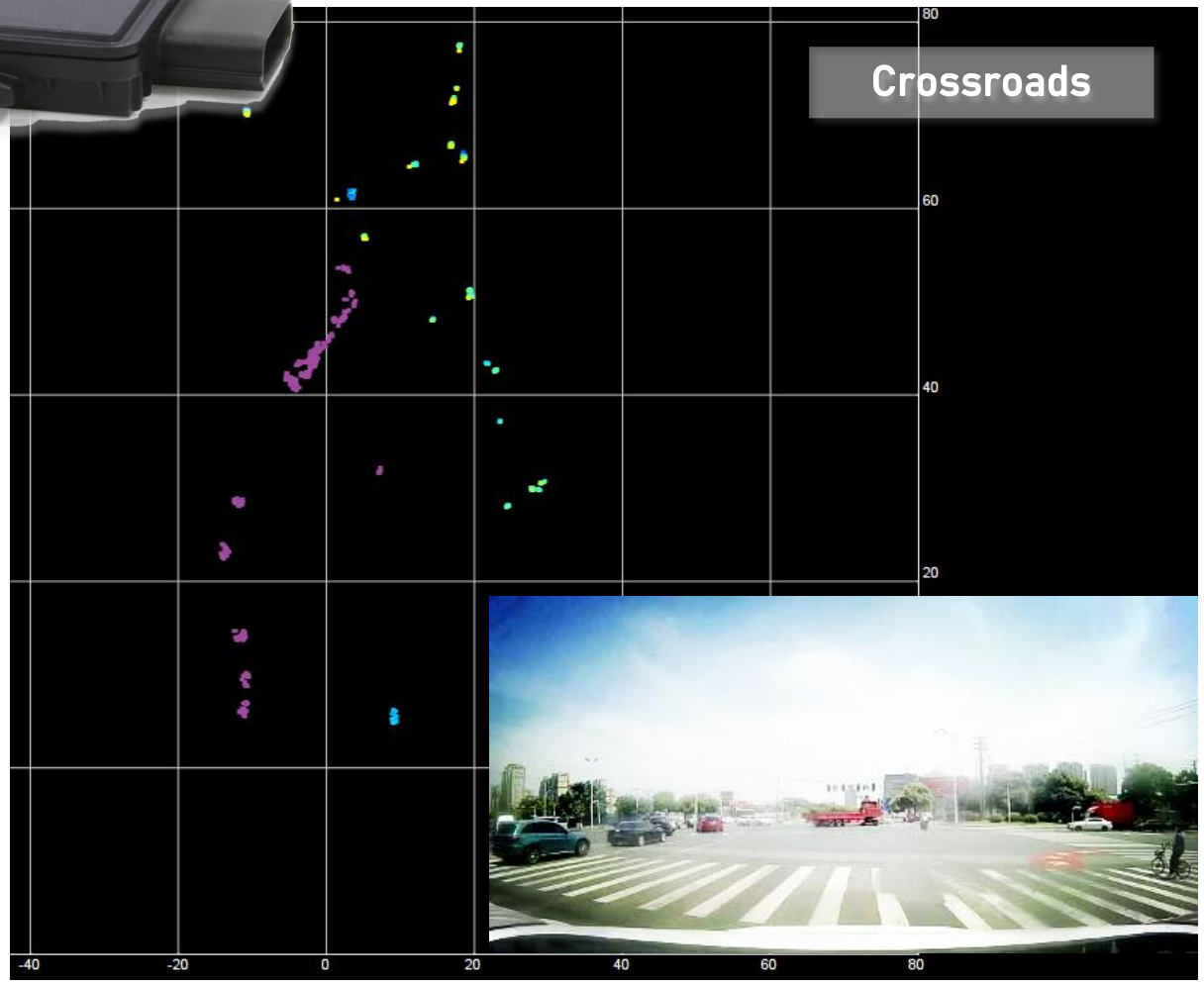
道路测试场景
Road Test Scenario



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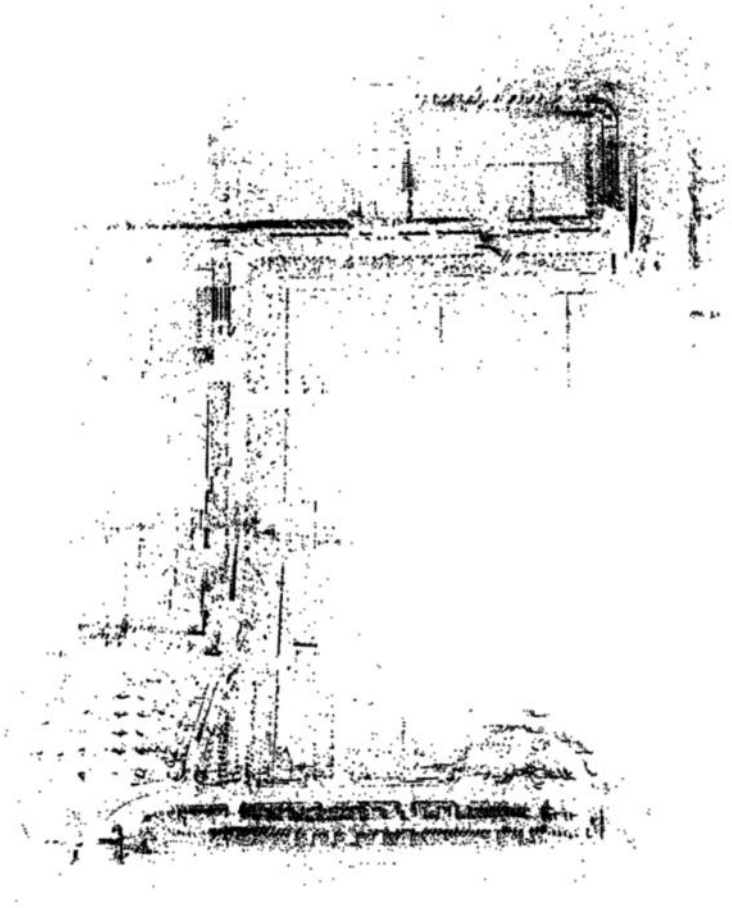
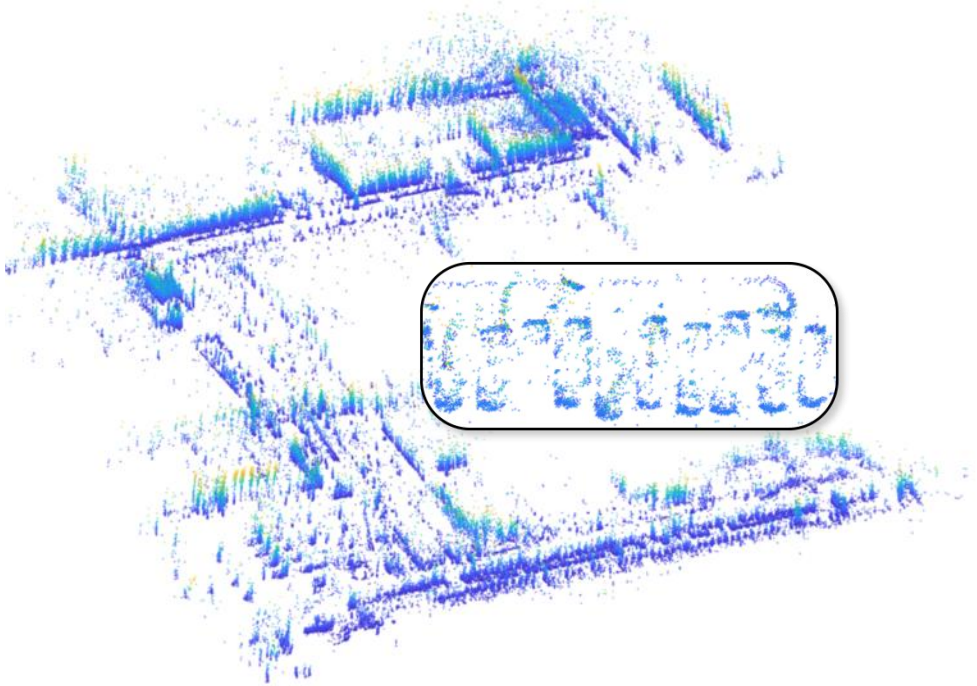
点云建图
SLAM

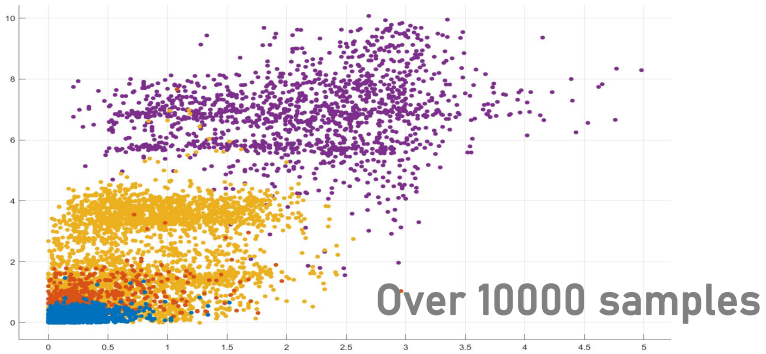




目标分类
Oject Classification

	大型车	轿车	非机动车	行人
行人	97.1%	1.1%	1.1%	0.1%
非机动车	1.8%	77.4%	19.1%	1.7%
轿车	0.5%	8.9%	85.2%	5.4%
大型车		2.1%	17.0%	81.0%

	大型车	轿车	非机动车	行人
行人	98.7%	0.7%	0.5%	0.1%
非机动车	0.9%	93.3%	4.4%	1.4%
轿车	0.4%	5.5%	88.5%	5.5%
大型车		2.0%	8.5%	89.5%



基于目标特征的机器学习

- Input：距离，尺寸，速度，**检测点分布，高度，解耦多普勒，RCS**

  ... 加速度，Yaw-rate

- Output：大型车、轿车、非机动车、行人；置信概率

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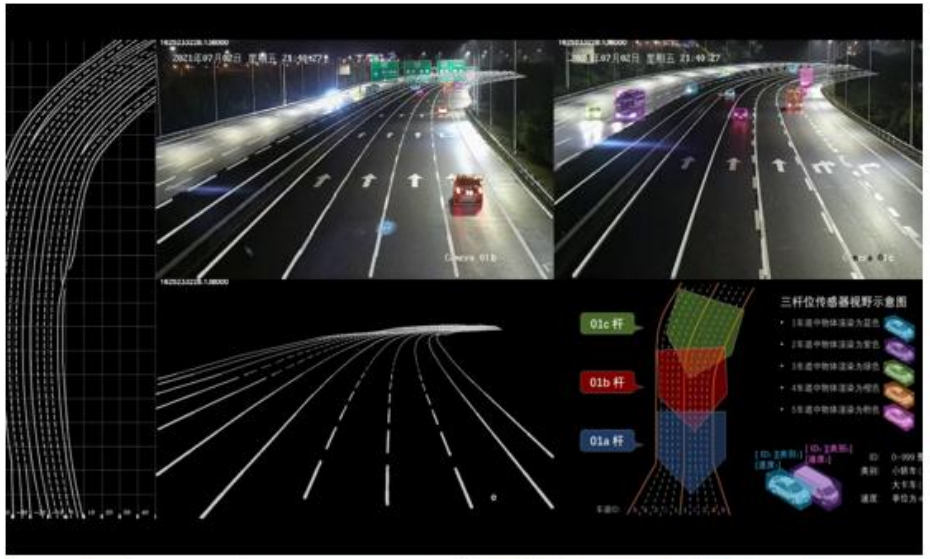
5H交通雷达
5H Traffic Radar



5H Traffic Radar

Holographic Perception, Hyper Intelligence

Hyper Precision, Hyper Resolution, Hyper Range

0.6 deg
AZ Resolution

1.5 km
MAX Range

0.1 deg
AZ Precision

10~14
Lanes

雷达感知、数字孪生、车路协同

- 车道级定位
- 高精地图融合
- 交通事件
- 云端自学习
- 大、小车分类
- 视觉投影
- 实时数字孪生

HAWKEYE
隼眼科技

77GHz毫米波雷达

HAWKEYE

隼眼科技

江苏省南京市江宁区秣周东路9号（中国无线谷）

info@ehawkeye.net

让 毫 米 波 技 术 触 手 可 及