Increasing the Sensing Spatial Resolution and Future Trends

12.3.2024
RF Summit Finland
Mervi Hirvonen and Henna Paaso

Outline

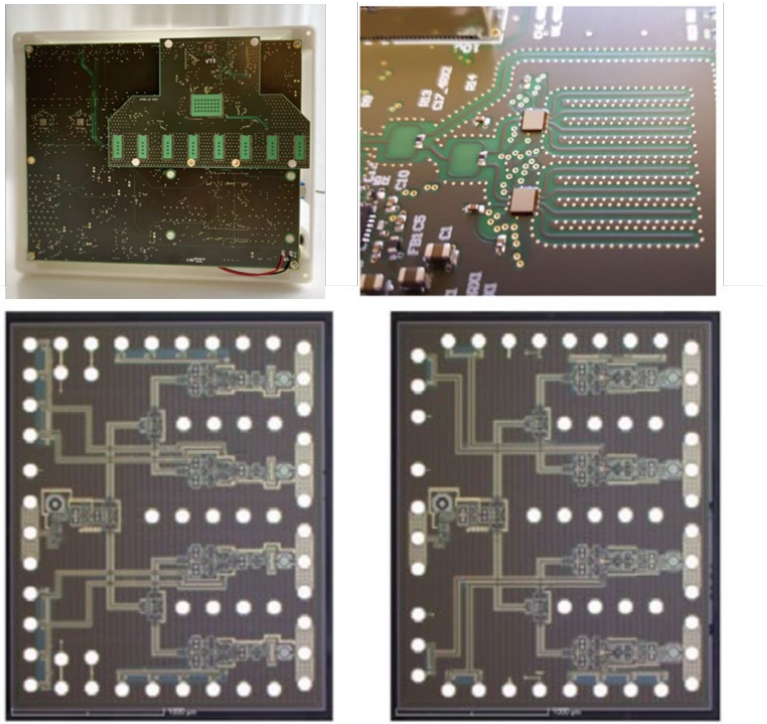
- Introduction
- FMCW radars
- JCAS
- Extrapolation algorithms
- Fast Burg algorithm
- Results

Introduction

- For imaging radars, angular resolution plays an increasingly important role
  - For example, automotive, aviation, people tracking, JCAS
- The spatial resolution is directly dependent on the size of the antenna aperture, and in MIMO cases the number of channels
- This leads to high complexity
  - High hardware cost
  - Large amount of data
  - Energy consumption
  - Serious heat dissipation problem

FMCW MIMO radars

- The VTT's MIMO frequency modulated continuous wave (FMCW) radar operates at 60 GHz and is based on VTTs own modular chipsets
- Manufactured with SiGe technology at IHP Microelectronics
- Frequency division MIMO technique allows the detection of moving targets
- 8 TX and 8 RX channels



FMCW MIMO radars

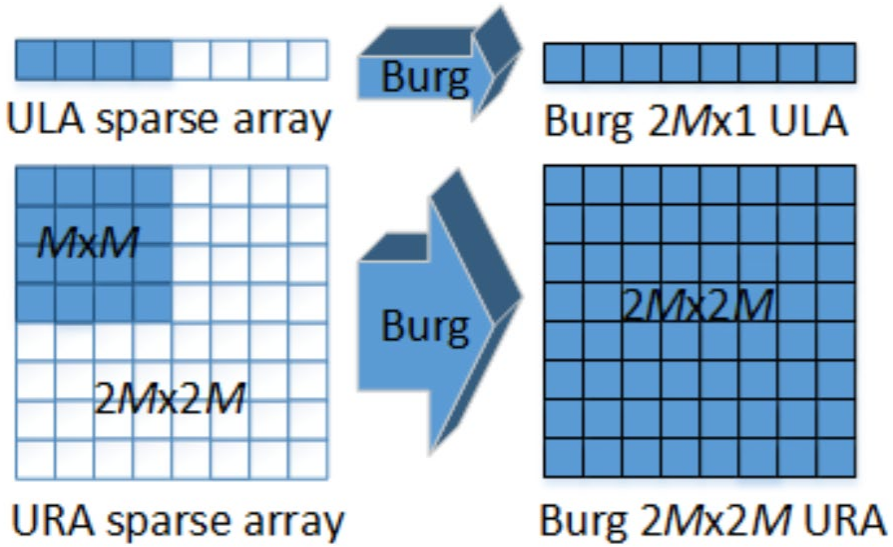
- The VTT's MIMO frequency modulated continuous wave (FMCW) radar operates at 34 GHz and is based on VTTs own modular chipsets
- 4 TX and 24 RX channels

JCAS

- In Joint Communication and Sensing, JCAS, telecommunications hardware and waveforms are used in sensing
- Complex sensing systems compared to FMCW
- Applications
  - People flow
  - Traffic
  - Environmental monitoring (flooding water, snow depth, road surface condition monitoring, local weather sensing)
- How to handle the complexity
  - Hybrid analog/digital beamforming
  - In fully digital systems virtual antenna elements through interpolation and/or extrapolation

Extrapolation algorithms

- Extrapolation algorithms extend the measurements from a small antenna array to a much larger virtual array through signal processing



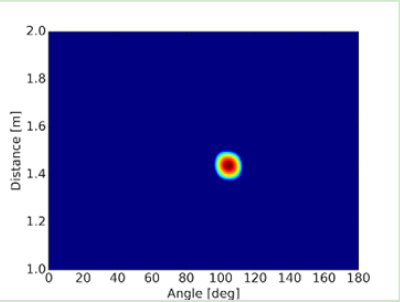
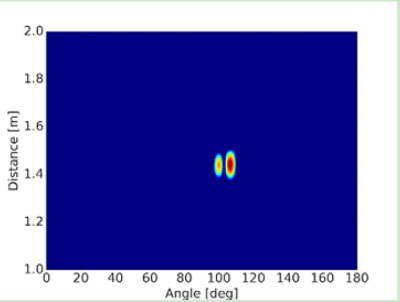
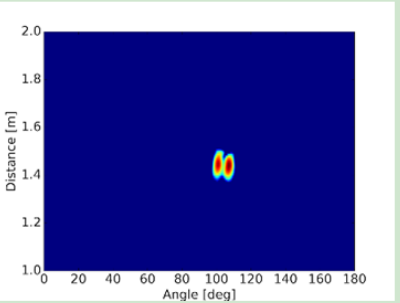
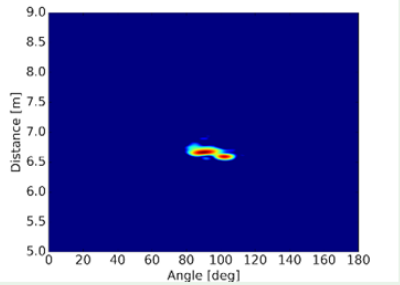
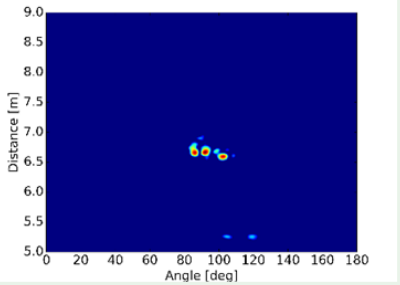
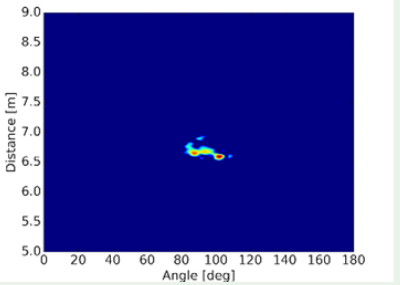
Extrapolation algorithms

- Signal extrapolation algorithms are very well studied in the field of spectral estimation
  - Autoregressive (AR) models: covariance, modified covariance, Yule-Walker, and Burg
  - The AR model predicts the time series data at a certain time from the linear sum of the previous data
  - Burg technique has high resolution for short data records and it produces always a stable model
  - Other AR models, like as covariance and modified covariance AR models produce unstable models and Yule-Walker model performs well only for large data records

Fast Burg algorithm

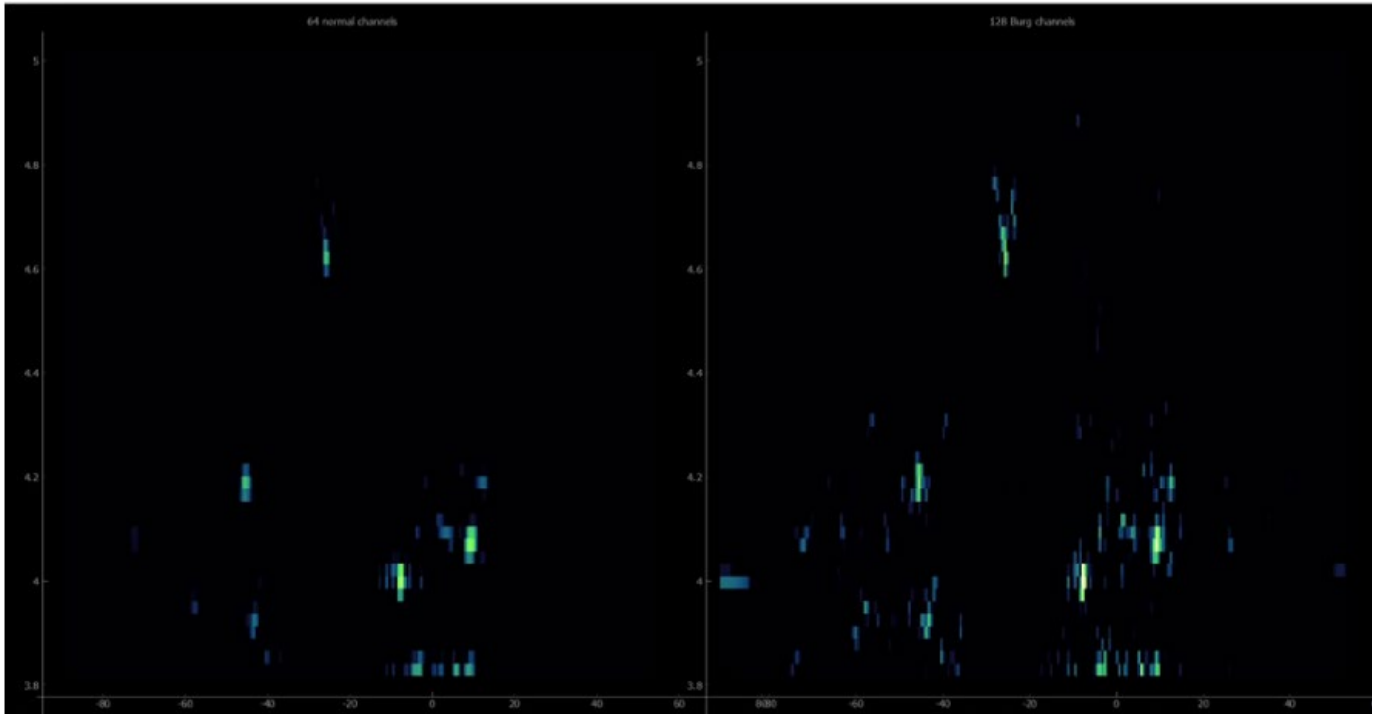
- Traditional Burg algorithm can be readily found for example in Mathworks and Python spectrum libraries, but it is extremely slow
- Our fast Burg algorithm utilizes matrix multiplication that we can estimate all range bins at the same time
- We have improved the calculation time considerably
  - It is 14.5 times faster compared to the conventional Burg algorithm, when 64 radar channels was used, and the AR order was 48
- Our new fast Burg algorithm can be used in real time measurements

Fast Burg algorithm, experimental resuls, FMCW

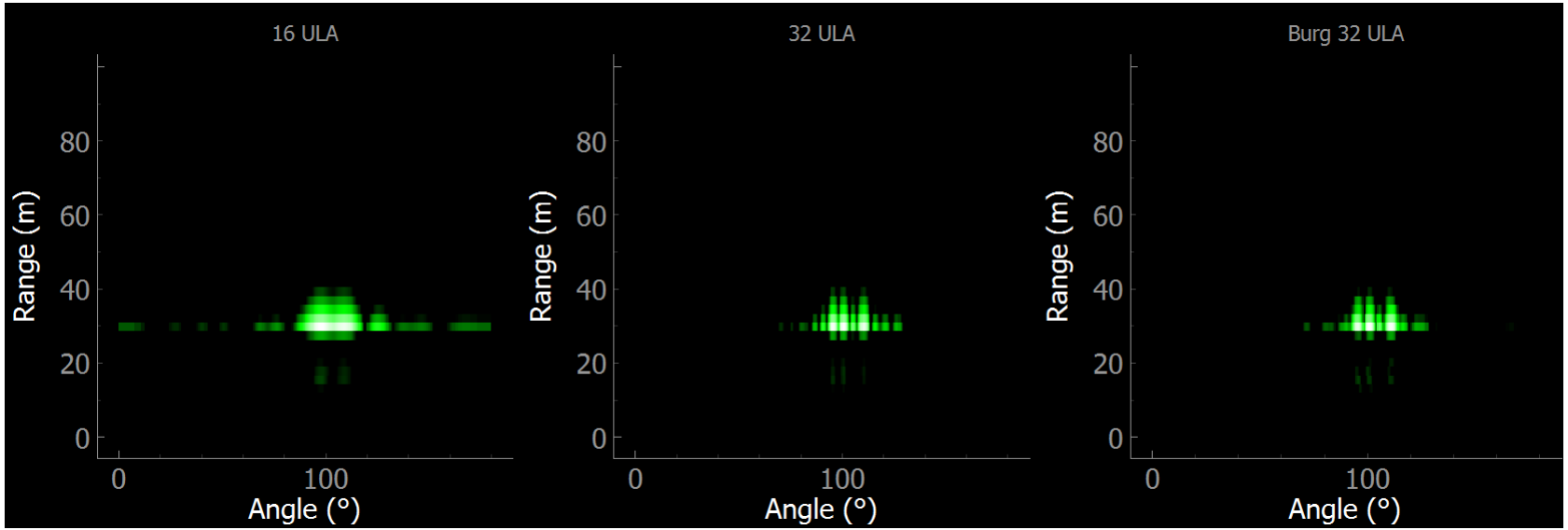
Measurement cases	15 MIMO virtual channels	29 MIMO virtual channels	15 virtual + 14 Burg MIMO channels
Two metallic poles 8° apart from each other. Range 1.5 m			
Three humans were standing close to each other Range: 7 m			

H. Paaso and M. Hirvonen, ”Fast super-resolution Burg algorithm for increasing the radar angular resolution”, IEEE/MTT-S International Microwave Symposium - IMS 2023

Fast Burg algorithm, experimental resuls, FMCW



Fast Burg algorithm, JCAS simulation results



Conclusions

- In MIMO radars increasing the spatial resolution requires multiple channels and thus increases the complexity of the system
- JCAS systems further increase the complexity
- In fully digital MIMO systems interpolation and extrapolation algorithms can be utilized to increase the spatial resolution through virtual channels
- Fast Burg algorithm can increase the spatial resolution in almost real time both in FMCW and JCAS systems