DOA based Signal Combining aided Automatic Modulation Recognition/Demodulation for Surveillance System

Hung Chin Tan Kei Sakaguchi Jun-ichi Takada Kiyomichi Araki

Tokyo Institute of Technology, Tokyo JAPAN.

Contents

- Background (radio surveillance system for HF band)
- Proposed surveillance system architecture
- Computer simulation
- DSP implementation
- Conclusion

Unlicensed Radio & Surveillance System

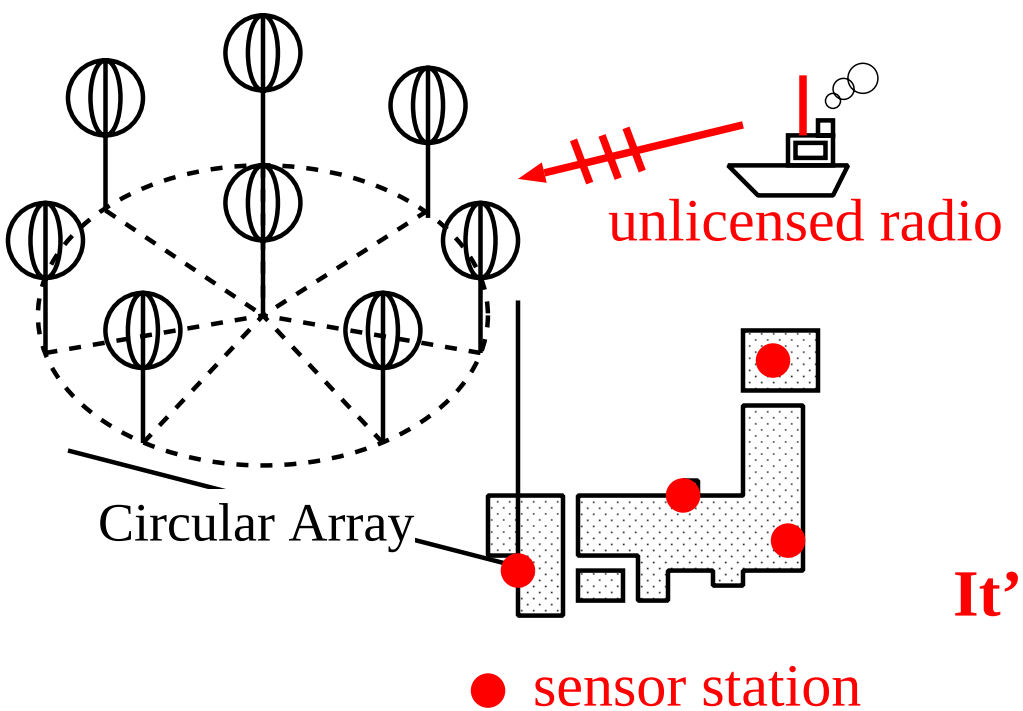
Mobile Commun. Research Group, Tokyo Institute of Technology

Detected unlicensed radio in JAPAN

personal	amateur	broadcasting	others	total
16,660	9,400	6,651	1,356	34,067

@2000

DEURAS-H system (DEtect Unlicensed RAdio Stations in HF band)



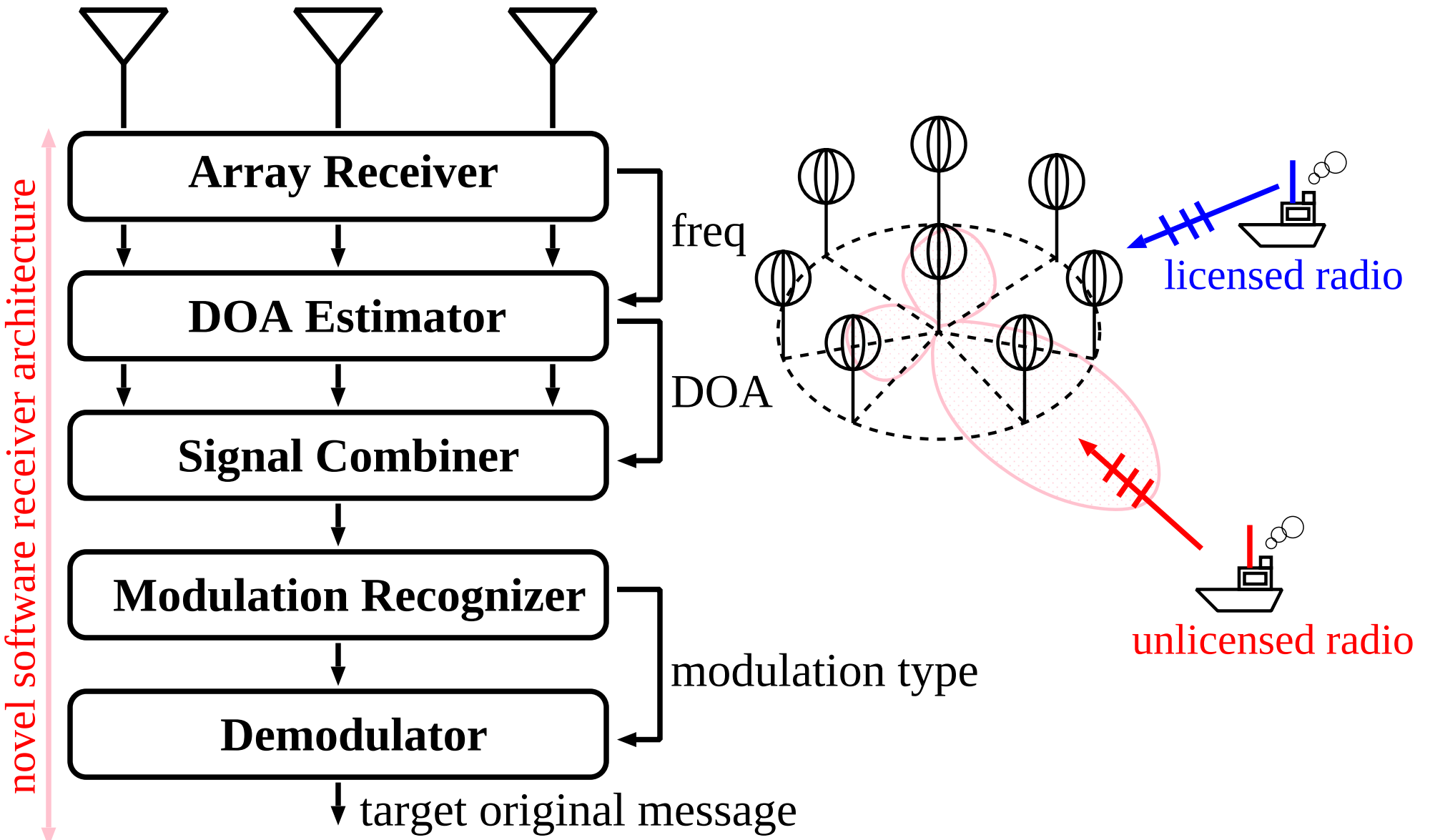
Specifications

frequency	100kHz - 30MHz
functions	direction finder (MUSIC) frequency analyzer

It's not enough in jamming scenario!

Proposed Surveillance System

Mobile Commun. Research Group, Tokyo Institute of Technology

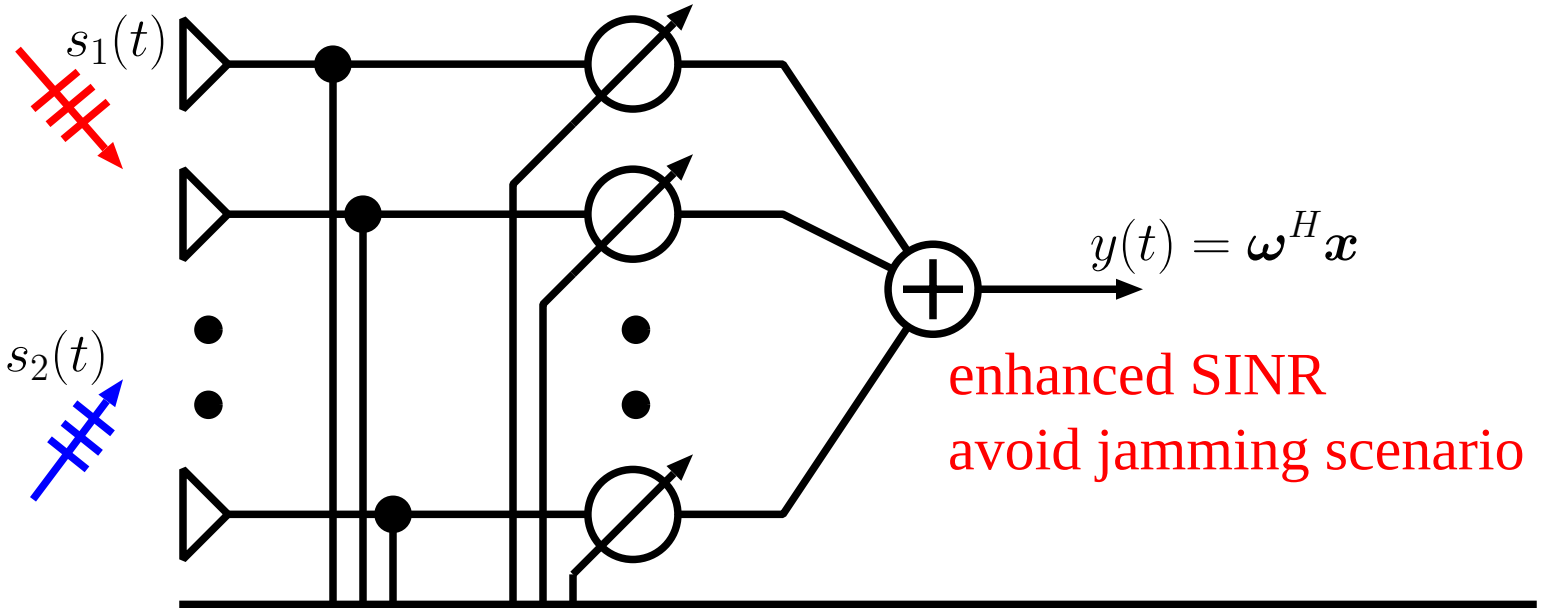


Contents

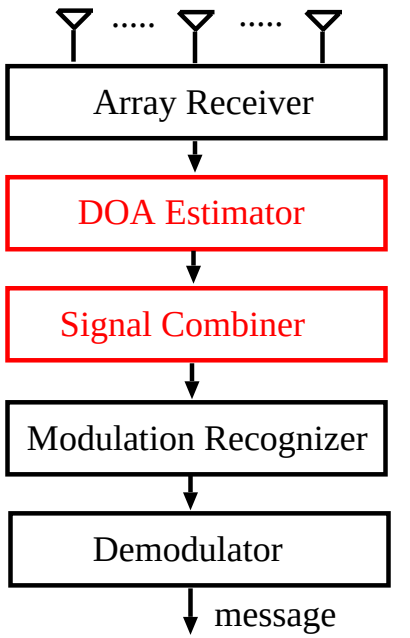
- Background (radio surveillance system for HF band)
- Proposed surveillance system architecture
- Computer simulation
- DSP implementation
- Conclusion

DOA Estimation & Signal Combining

Mobile Commun. Research Group, Tokyo Institute of Technology



enhanced SINR
avoid jamming scenario



Received signal

$$\boldsymbol{x} = \boldsymbol{v}(\theta_1, \phi_1)s_1(t) + \boldsymbol{v}(\theta_2, \phi_2)s_2(t) + \boldsymbol{n}$$

$\boldsymbol{v}$: array mode vector for UCA

UCA-ESPRIT

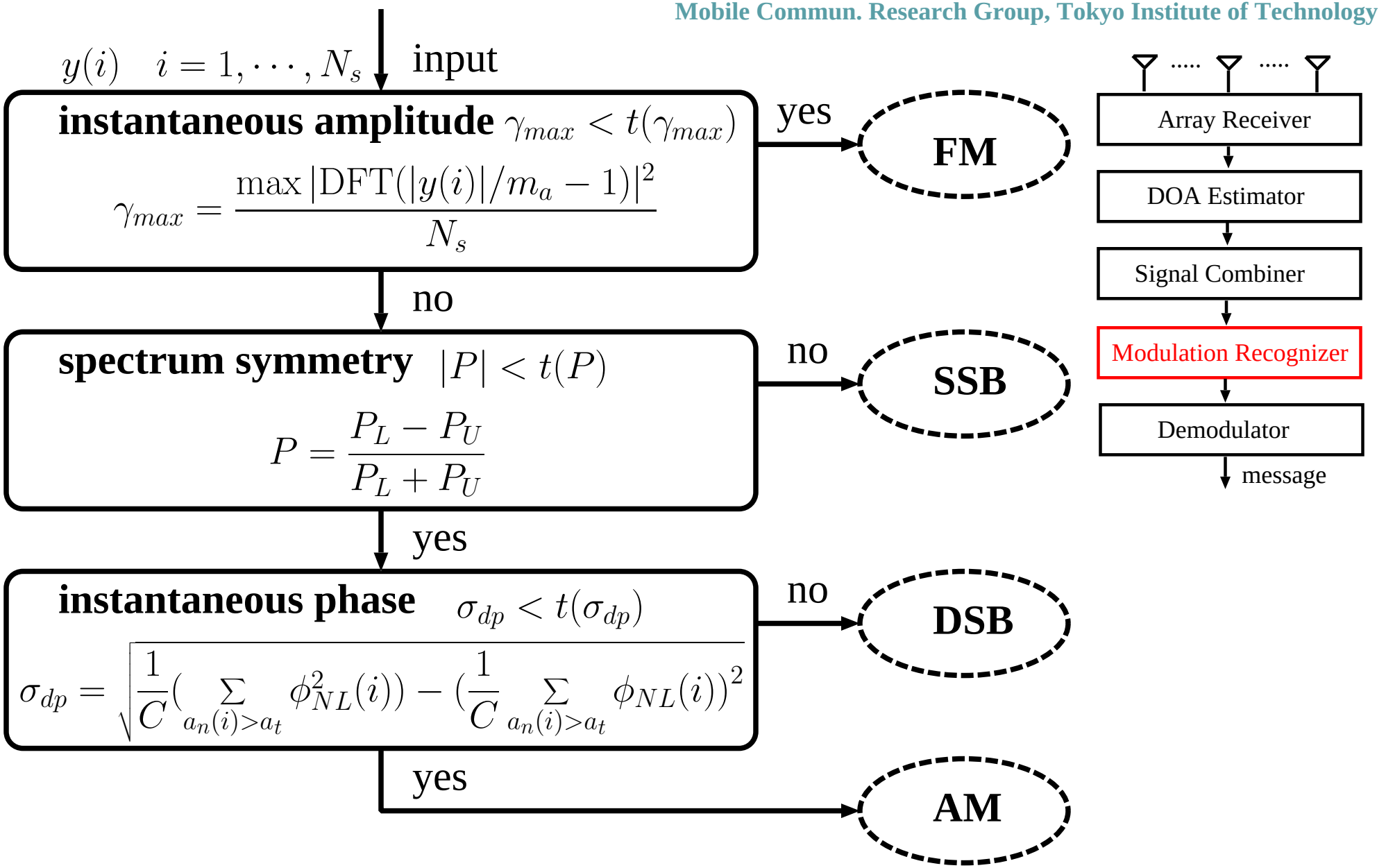
estimates azimuth angles $\hat{\theta}_i$ and elevation angles $\hat{\phi}_i$

Zero-Forcing Beamformer

$$\boldsymbol{\omega}_1 = \boldsymbol{V}(\boldsymbol{V}^H\boldsymbol{V})^{-1}\boldsymbol{u}_1 \quad \text{where } \boldsymbol{V} = [\boldsymbol{v}(\hat{\theta}_1, \hat{\phi}_1), \boldsymbol{v}(\hat{\theta}_2, \hat{\phi}_2)]$$

Automatic Modulation Recognition

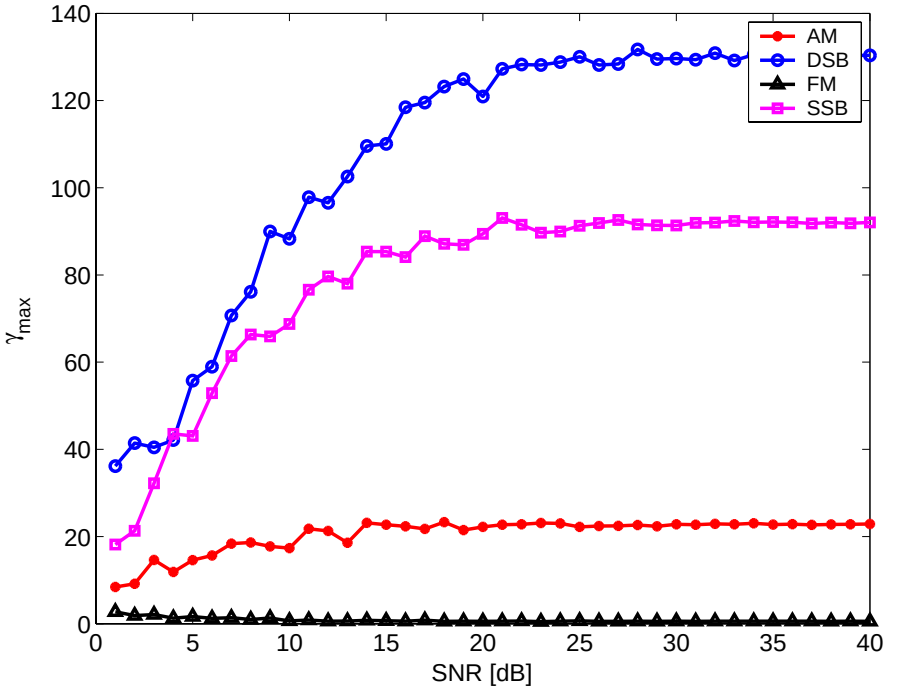
Mobile Commun. Research Group, Tokyo Institute of Technology

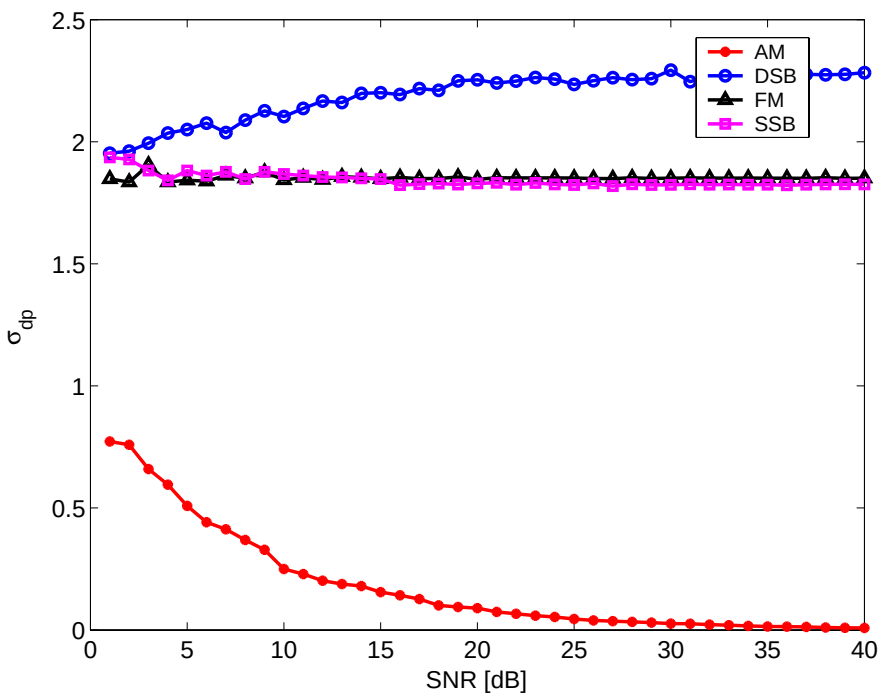


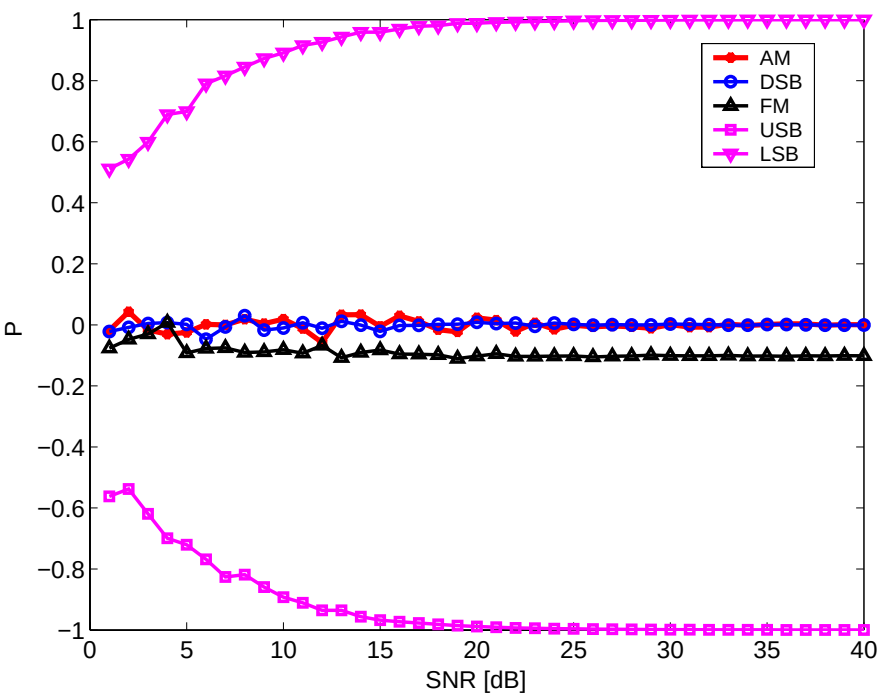
γ_{max}

σ_{dp}

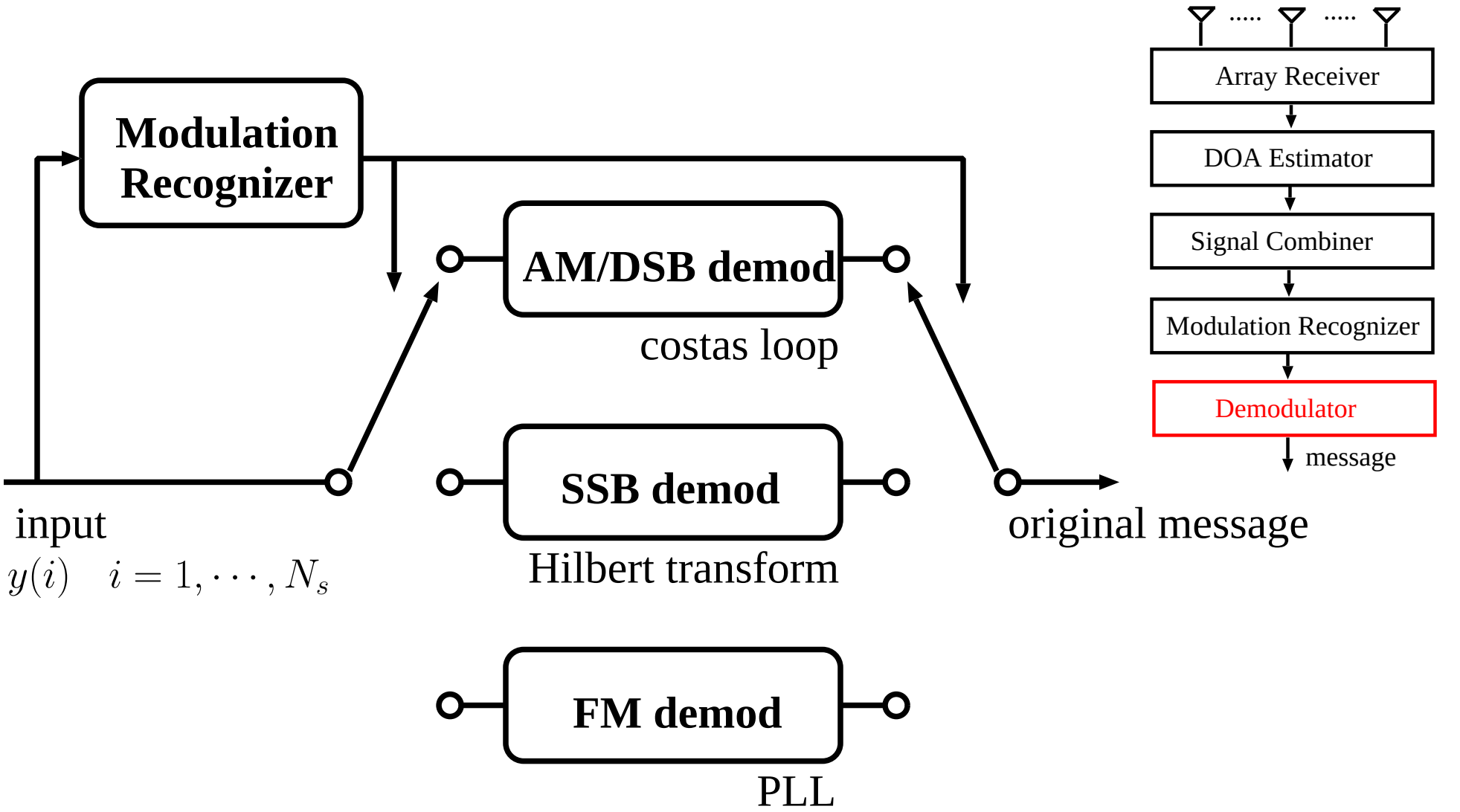
P







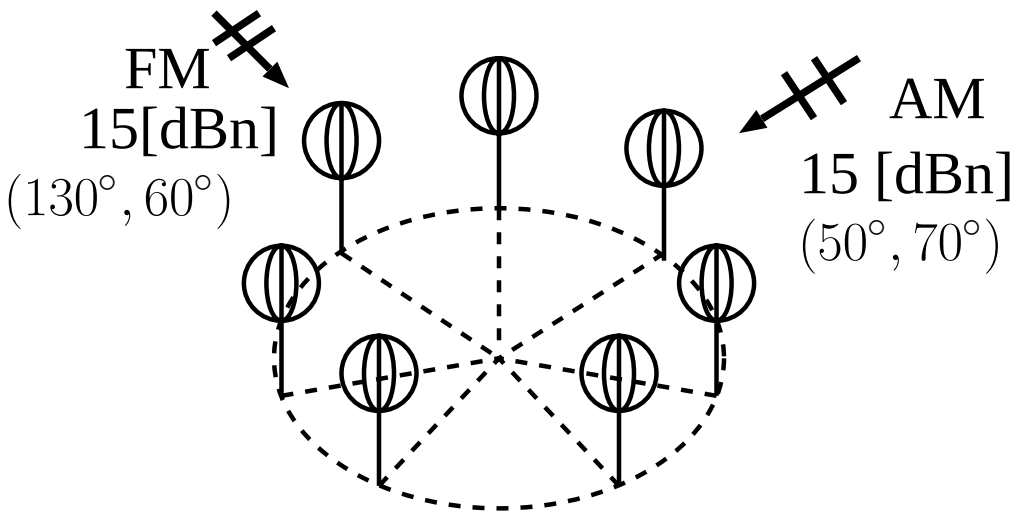
Adaptive Demodulation

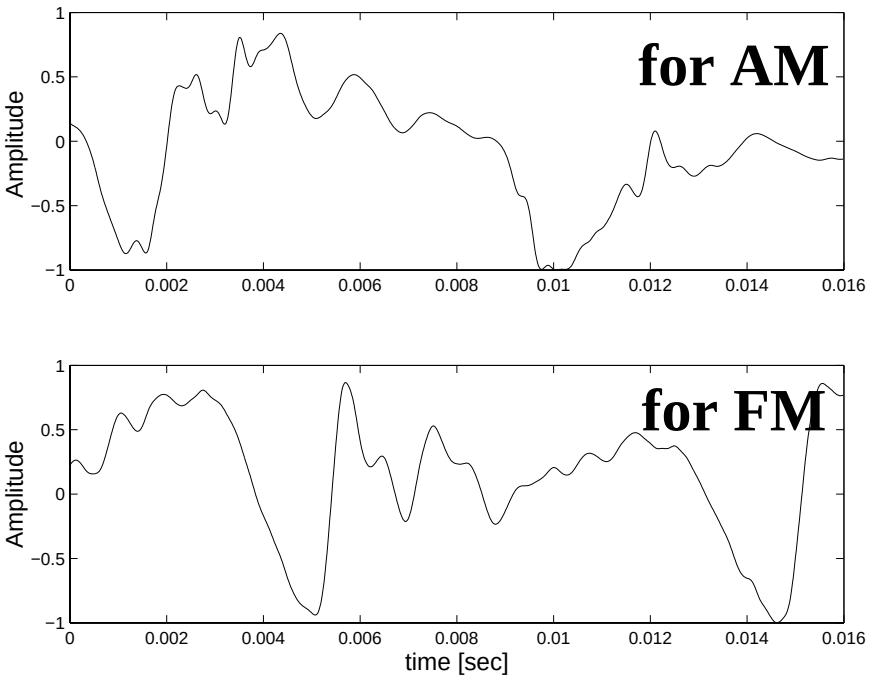


Contents

- Background (radio surveillance system for HF band)
- Proposed surveillance system architecture
- Computer simulation
- DSP implementation
- Conclusion

Simulation Condition





Key Feature	Threshold value
γ_{max}	6
P	0.8
σ_{dp}	0.4

1024 sample points in a segment (16[ms])

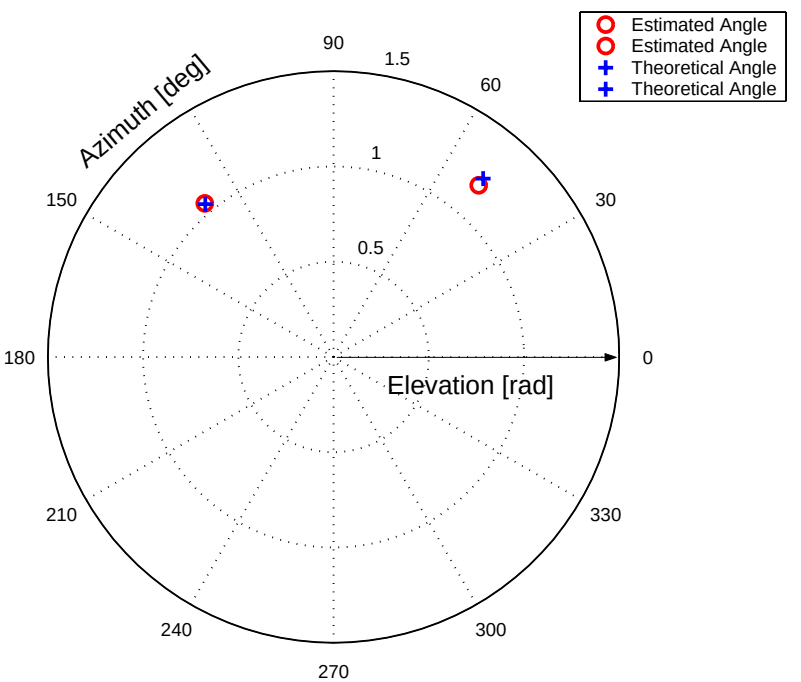
IF frequency : 18 [kHz]

Sampling rate : 64 [kHz]

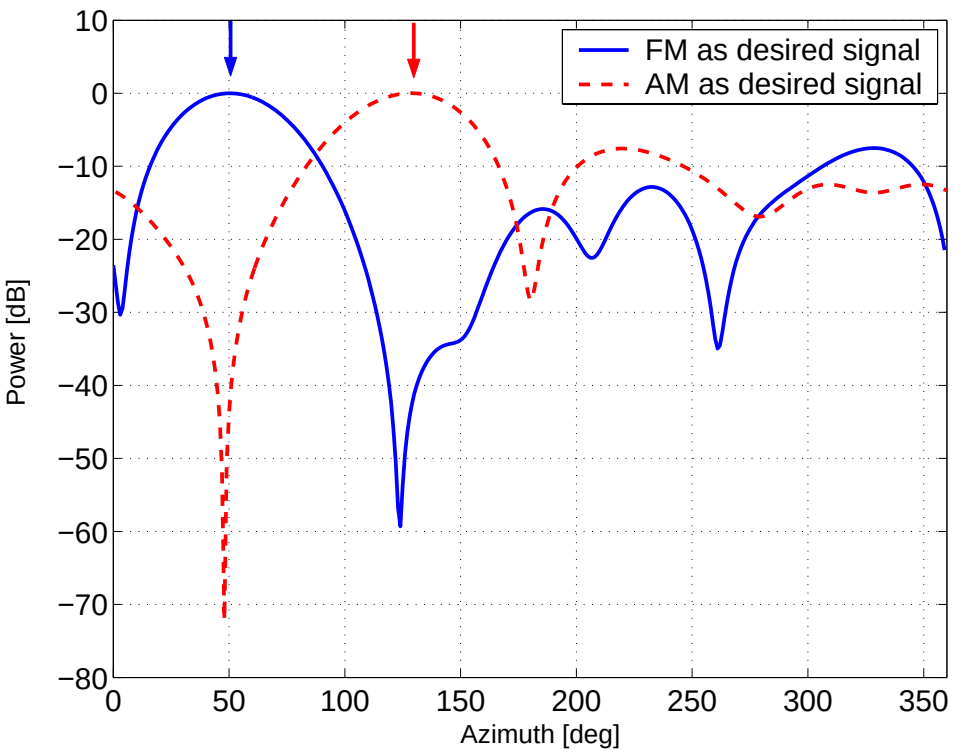
DOA Estimation & Signal Combining

Mobile Commun. Research Group, Tokyo Institute of Technology

Estimated DOA



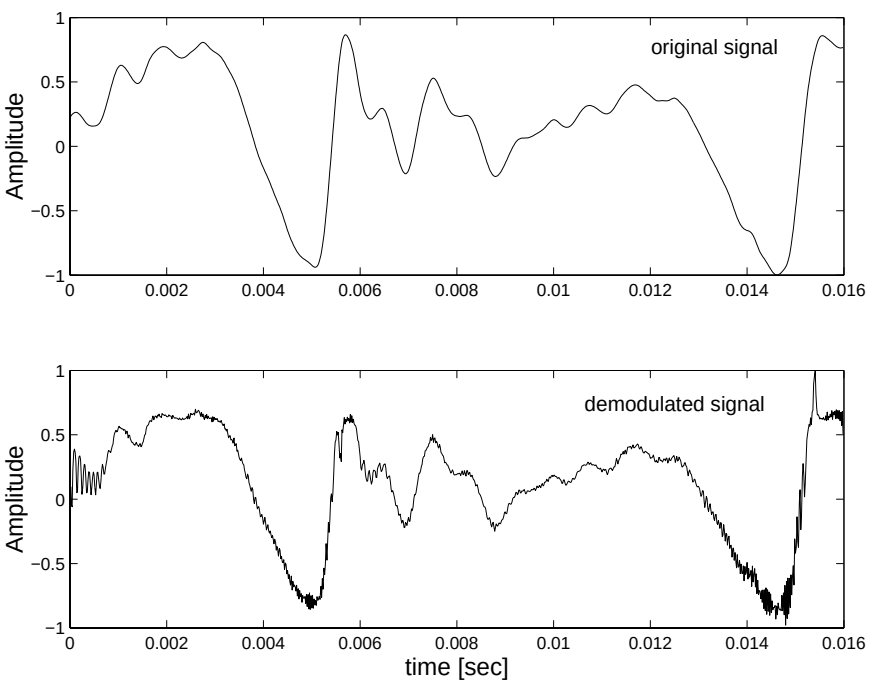
array beam pattern



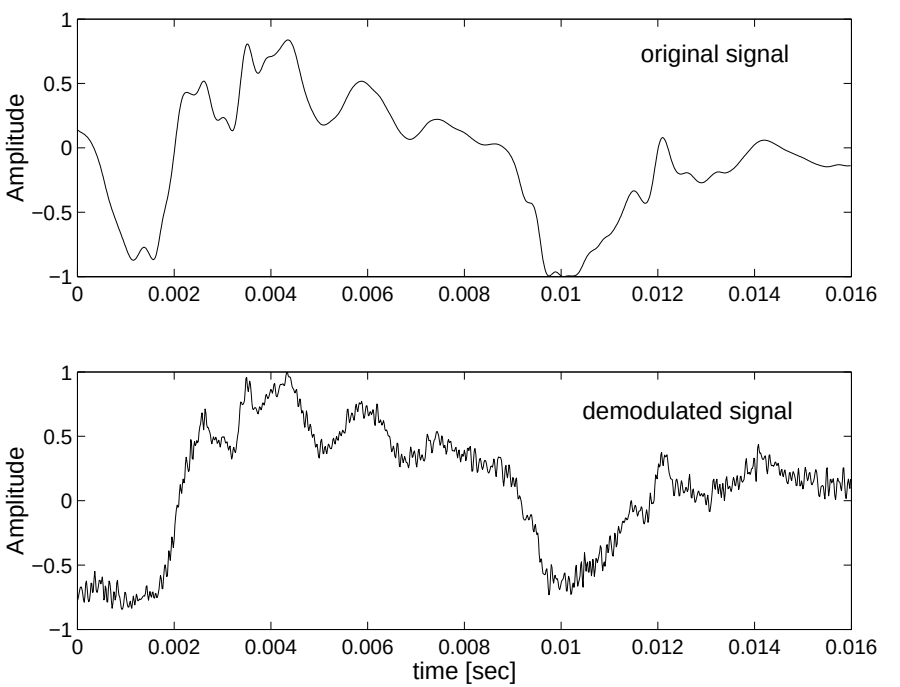
Modulation Recognition/Demodulation

Mobile Commun. Research Group, Tokyo Institute of Technology

Demodulated FM signal

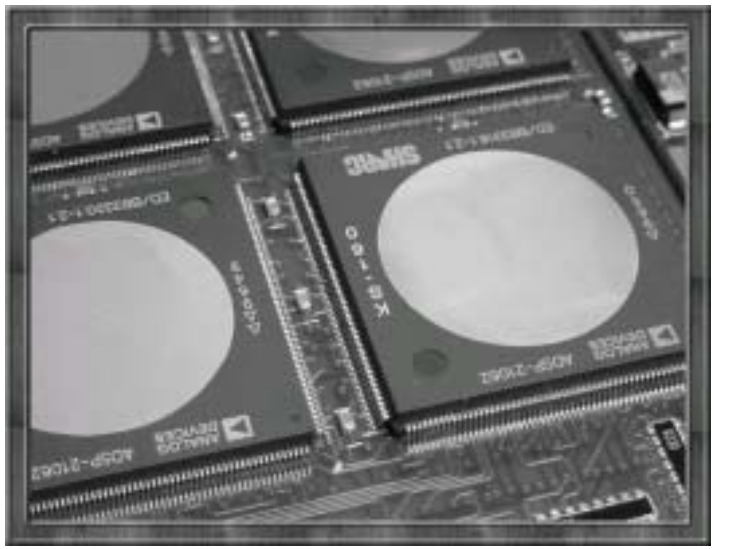


Demodulated AM signal



Contents

- Background (radio surveillance system for HF band)
- Proposed surveillance system architecture
- Computer simulation
- DSP implementation
- Conclusion



Calculation Precision & Process Time

	$\hat{\theta}_1[\mathrm{deg}]$	$\hat{\phi}_1[\mathrm{deg}]$	$\hat{\theta}_2[\mathrm{deg}]$	$\hat{\phi}_2[\mathrm{deg}]$	time[ms]
CPU x 1 Pen III 700 MHz	60.0955	60.0627	30.0118	30.0103	90
DSP x 8 SHARC 40 MHz	60.0786	60.0627	30.0489	30.0455	93

	# of DSPs	process time [ms]
DOA estimation & signal combining	4	13
Automatic modulation recognition	3	18
Demodulation	1	62
Total	8	93

We need 230[MHz] DSP but 3.9[GHz] CPU for realtime implementation!

Conclusion

Next Generation Surveillance System

- DOA Estimation
  gives the target direction
- Signal Combining
  enhances the target Signal to Interference power Ratio
- Automatic Modulation Recognition
  gives the target modulation type
- Adaptive Demodulation
  gives the target original information

These work together!!