RADE - Machine Learning for Speech over HF Radio

freedv.org

Supported by a grant from Amateur Radio Digital Communications

March 17, 2025

Outline

RADE Radio Auto-encoder

- Applying machine learning (ML) to send speech over HF radio
- Combines traditional DSP and modern ML to encode and decode speech
- Connect a PC running RADE to your SSB radio
- 8 kHz audio bandwidth, high quality speech
- Works at low and high SNRs, handles multipath fading

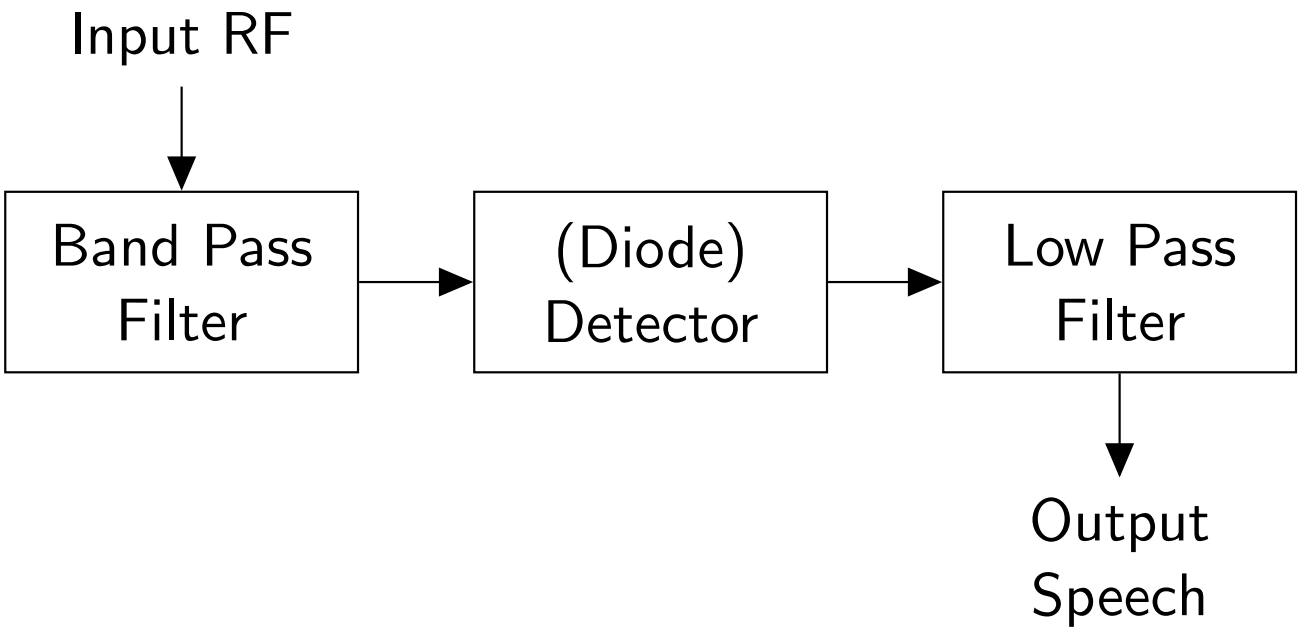
RADE Examples

- Texas to Australia, 25W, SNR 4 dB, deep fading ▸ Link
- 2000km Australian path, low and high SNR, barber pole fading ▸ Link

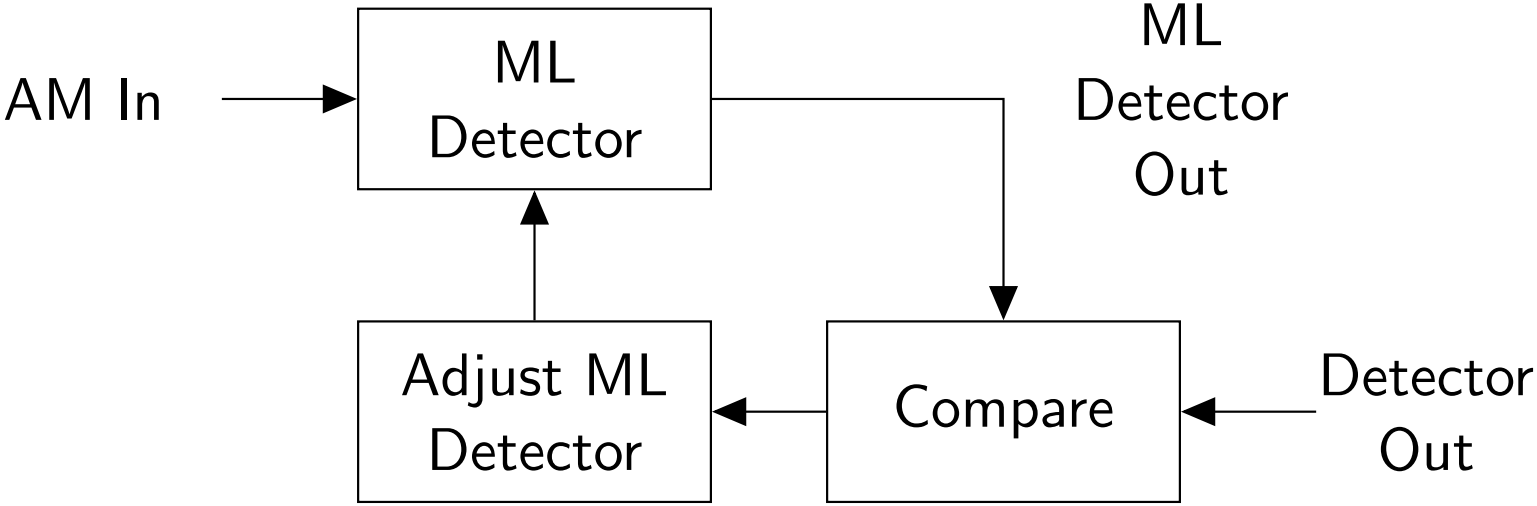
RADE is an outcome of the FreeDV Project ...

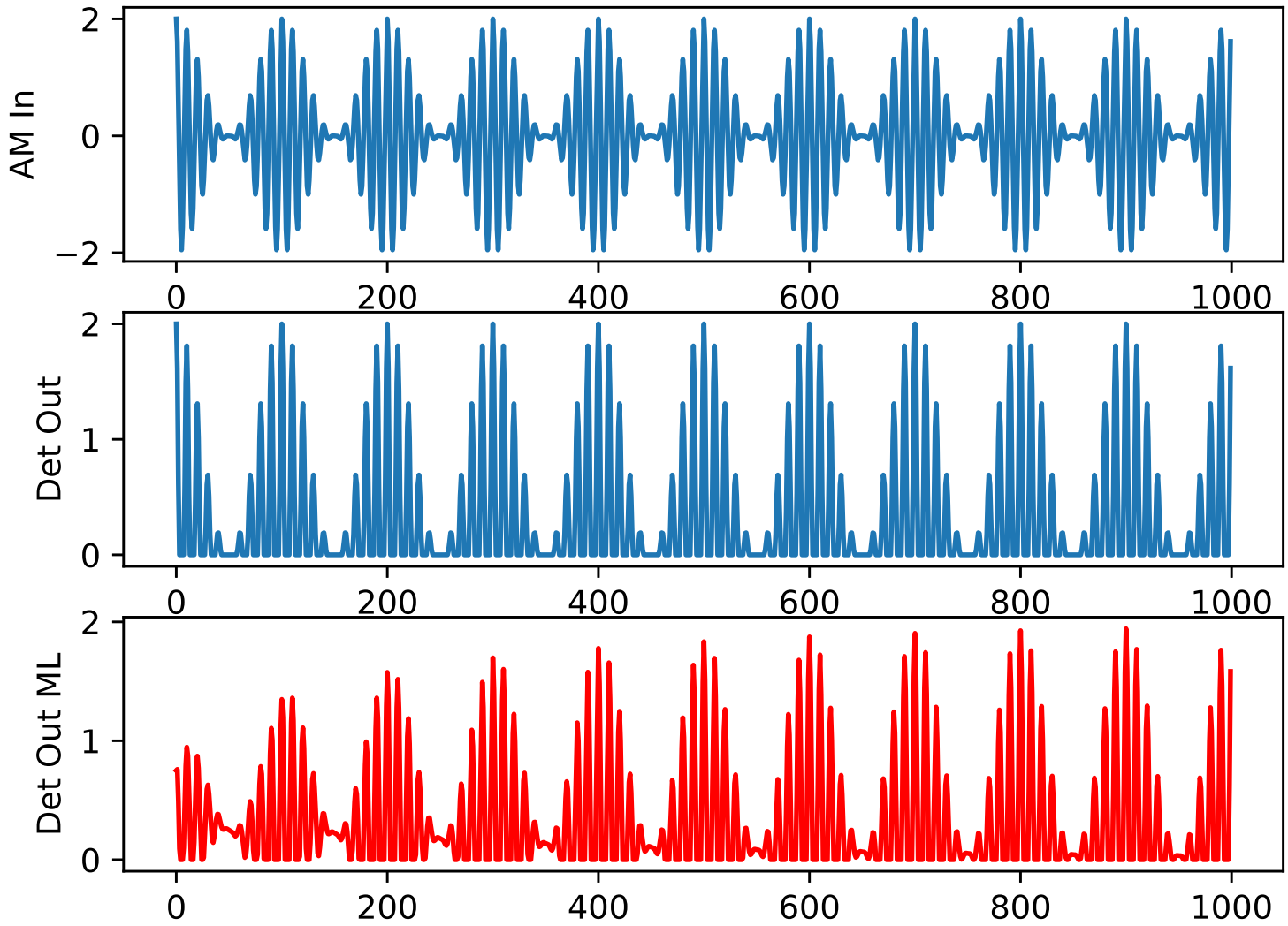
- Open source HF digital voice for amateur radio
- Since 2023, funded by an ARDC grant
- 6 person Project Leadership Team
- Financial sponsor is the Software Freedom Conservancy
- Project Goal: a voice mode competitive with SSB at high and low SNRs

- Previously, we would design a system
- Figure out all the signal processing steps
- With ML the emphasis is on training a neural network
- Consider an AM receiver example
- Lets build the Detector using machine learning



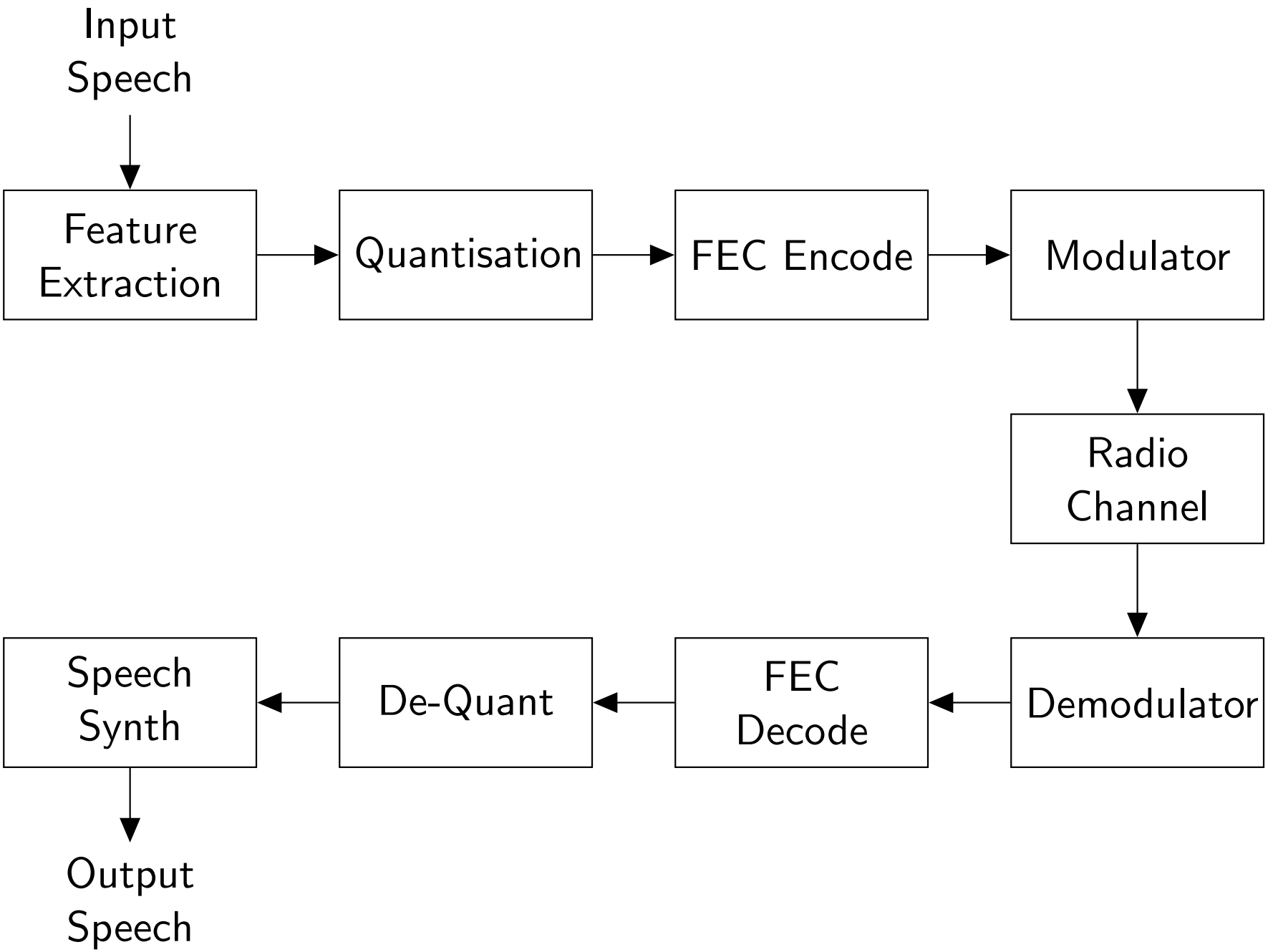
- Start with an untrained neural network
- Collect some training material
- Many examples of input and desired output
- Adjust the network so it matches the desired output

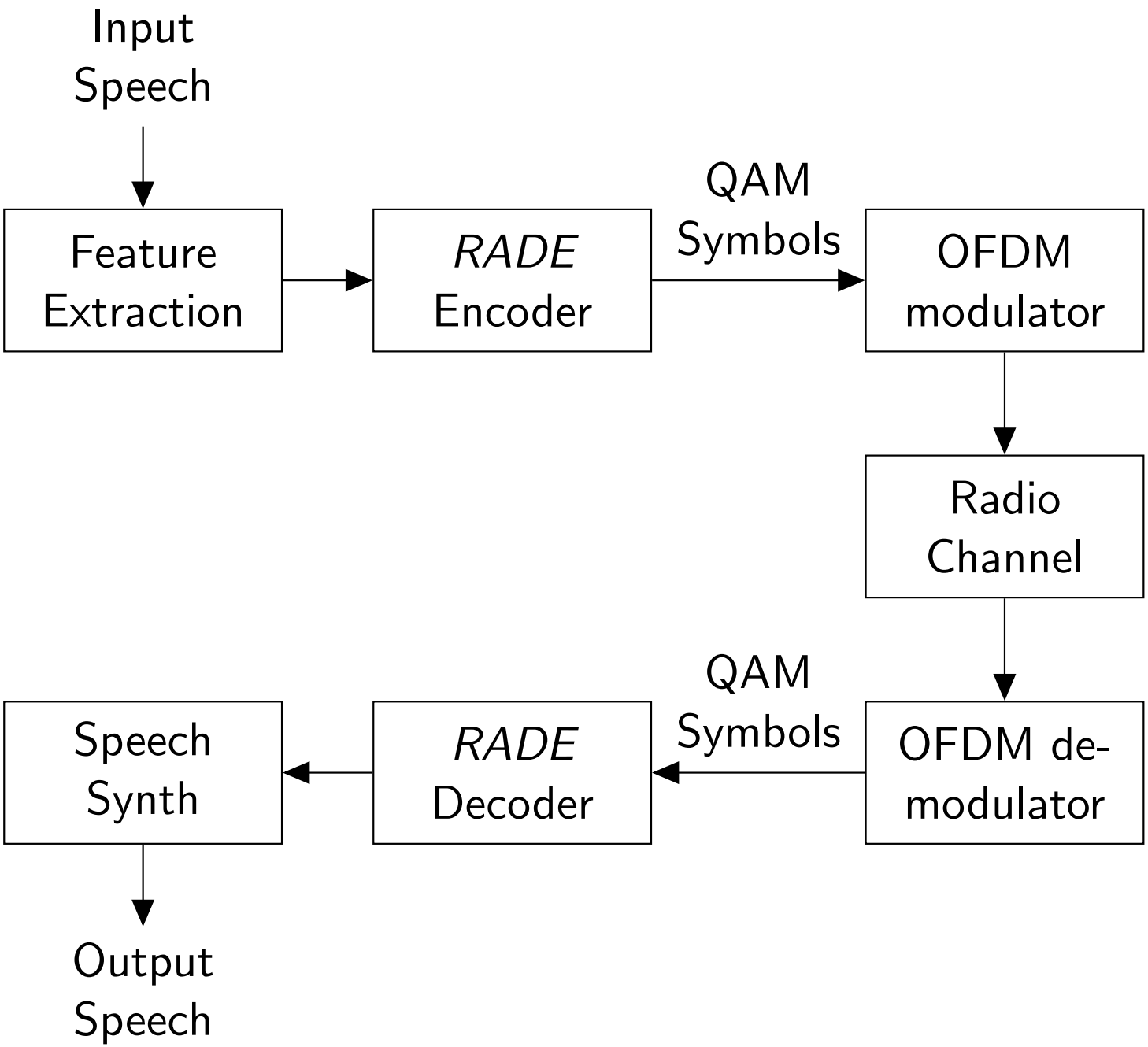



AM In
2
0
−2
0
200
400
600
800
1000
Det Out
2
1
0
0
200
400
600
800
1000
Det Out ML
2
1
0
0
200
400
600
800
1000

- Sometimes we don't know the best way to design something
- Real world problems are complex, perfect designs don't exist
- But we do have a good idea of what success looks (sounds) like
- So we just treat the system as a black box
- Show it examples of what we would like to see - and train
- ML has provided step changes in performance for many applications
- Including speech synthesis and compression

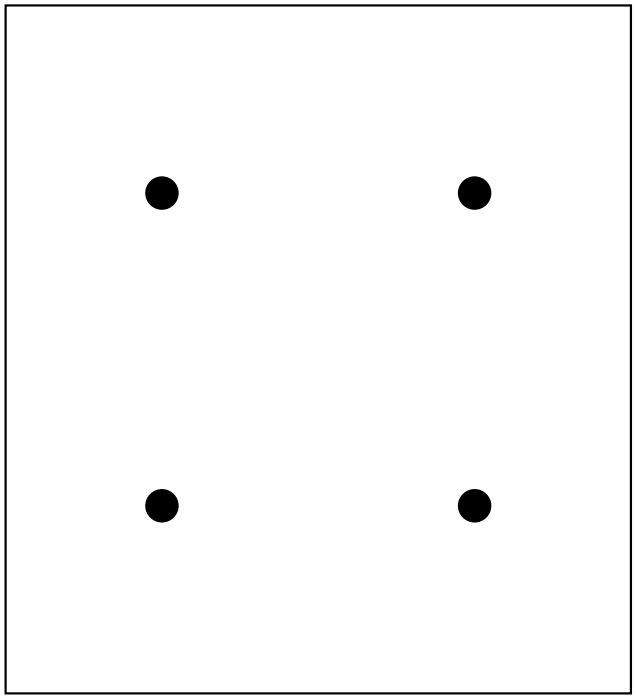
- Jean-Marc Valin (and team) - compressing speech for Internet applications
- Idea: could it could be applied to noisy signal over radio channels?
- Jean-Marc developed a quick proof of concept
- We wrapped a modem around it, developed a practical HF voice system
- Hams around the world helped crowd sourced the testing
- Mooneer Salem integrated RADE with the FreeDV GUI application


Input Speech
Feature Extraction
Quantisation
FEC Encode
Modulator
Radio Channel
Demodulator
FEC Decode
De-Quant
Speech Synth
Output Speech

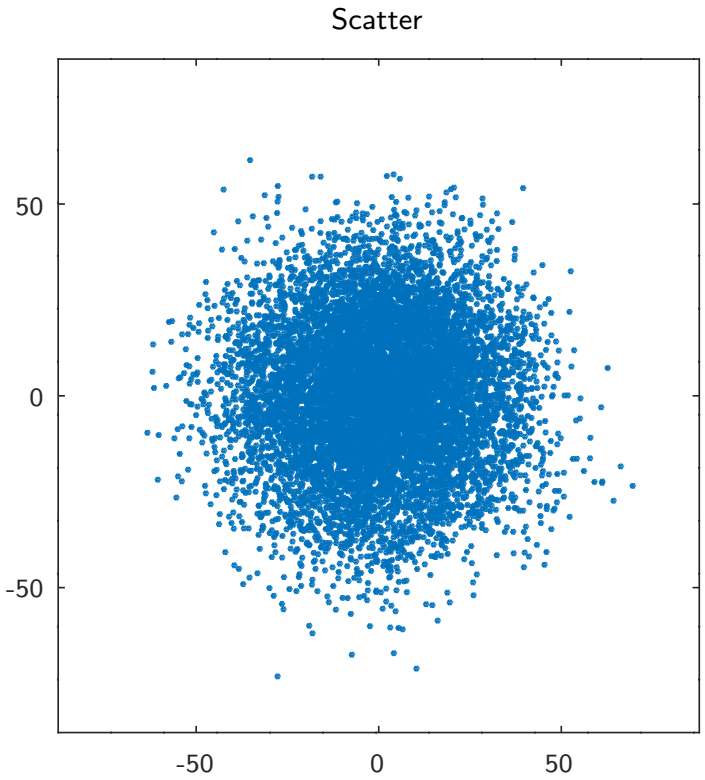

Input Speech
Feature Extraction
RADE Encoder
QAM Symbols
OFDM modulator
Radio Channel
QAM Symbols
OFDM de-modulator
RADE Decoder
Speech Synth
Output Speech

- Example of features - waterfall (aka spectrogram)
- A series of samples of the speech spectrum
- Encoder takes features and produces symbols we send over channel
- Decoder takes symbols and produces features
- Which are fed to a ML synthesiser to generate high quality speech
- Trained with 200 hours of speech, corrupted by noise and the HF channel
- Classical DSP modem wrapped around ML for synchronisation

QPSK Constellation



RADE Constellation



Conclusion

- Training versus Design
- RADE - Radio Autoencoder
- ML combined with classical DSP
- High quality speech over HF at low and high SNRs
- FreeDV GUI Application, sound card, SSB radio
- Supported by a grant from Amateur Radio Digital Communications
- Crowd sourced testing - thanks to many Hams around the world
- Developed by Hams for Hams

Links

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PSK Reporter	▸ Link
RADE Intro Doc	▸ Link