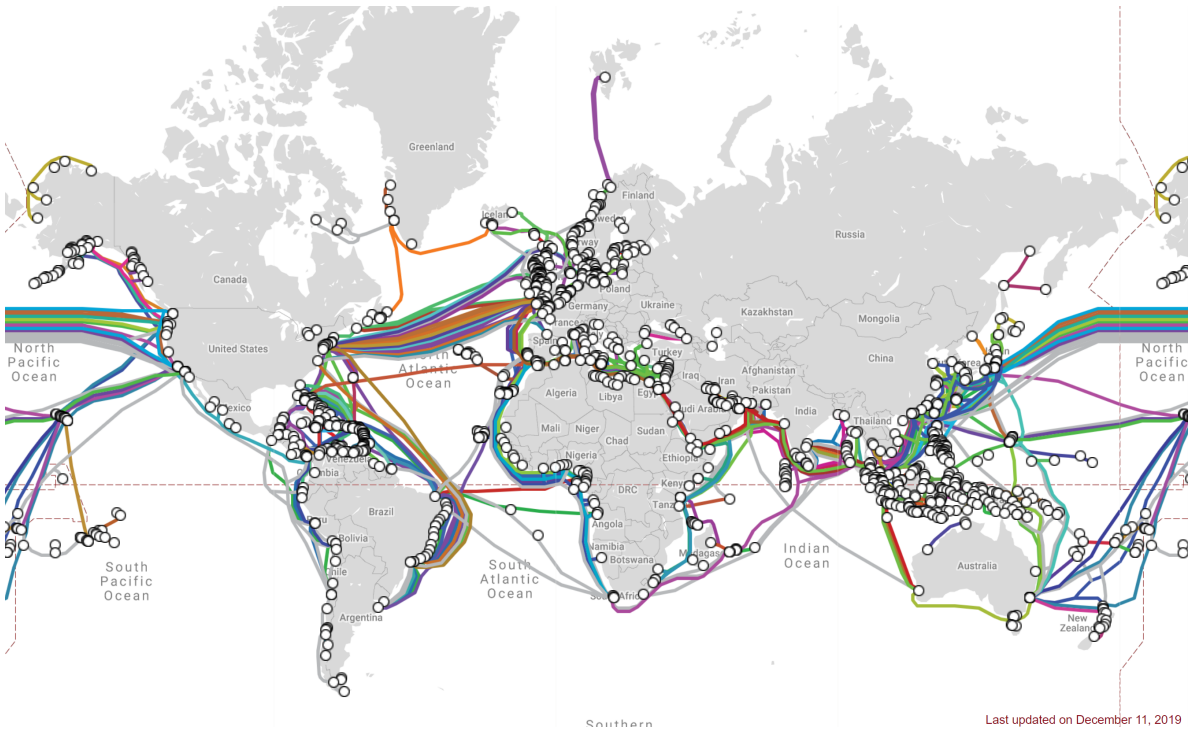
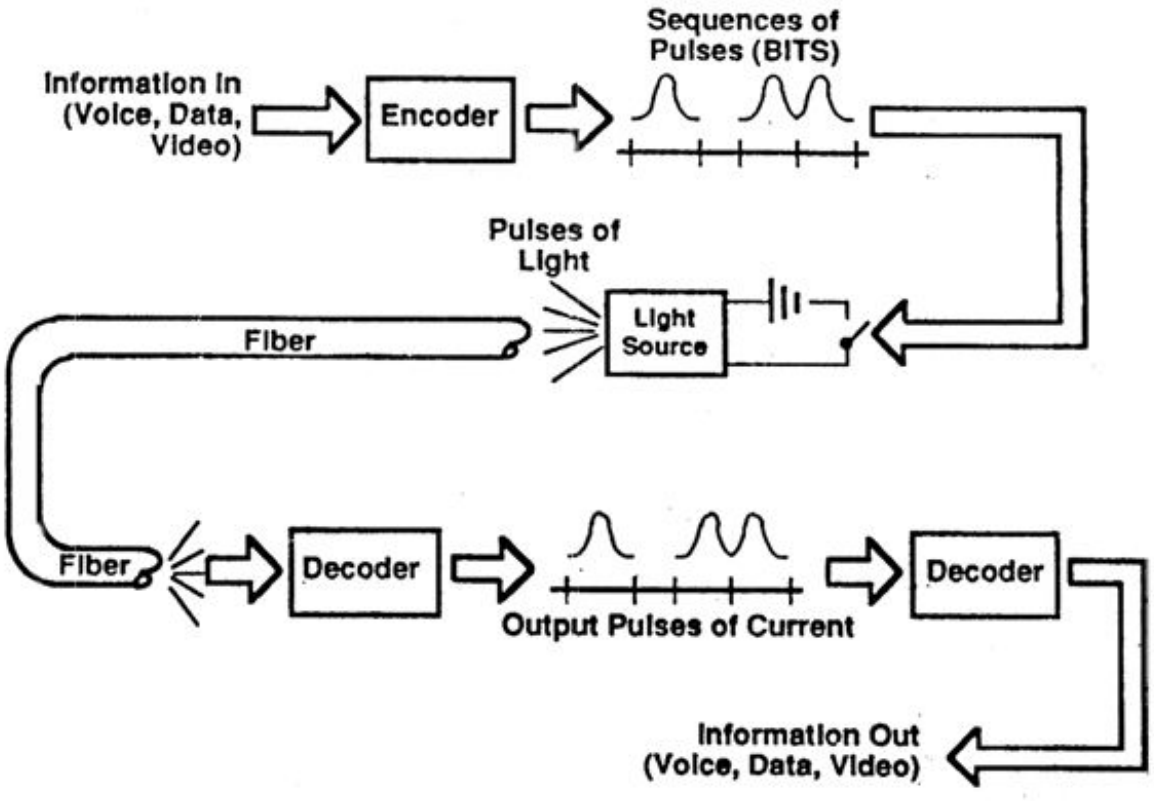
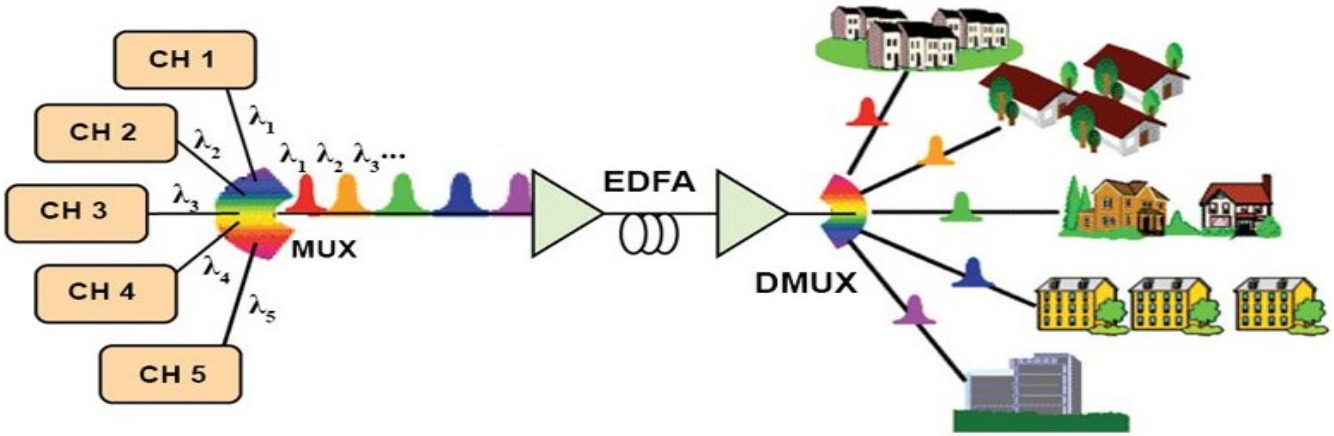
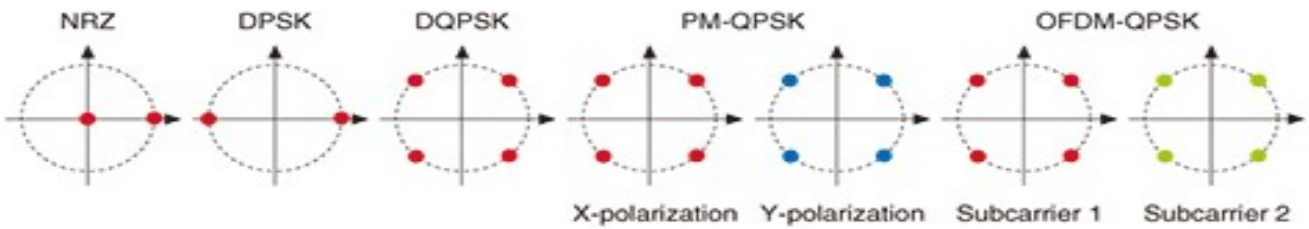
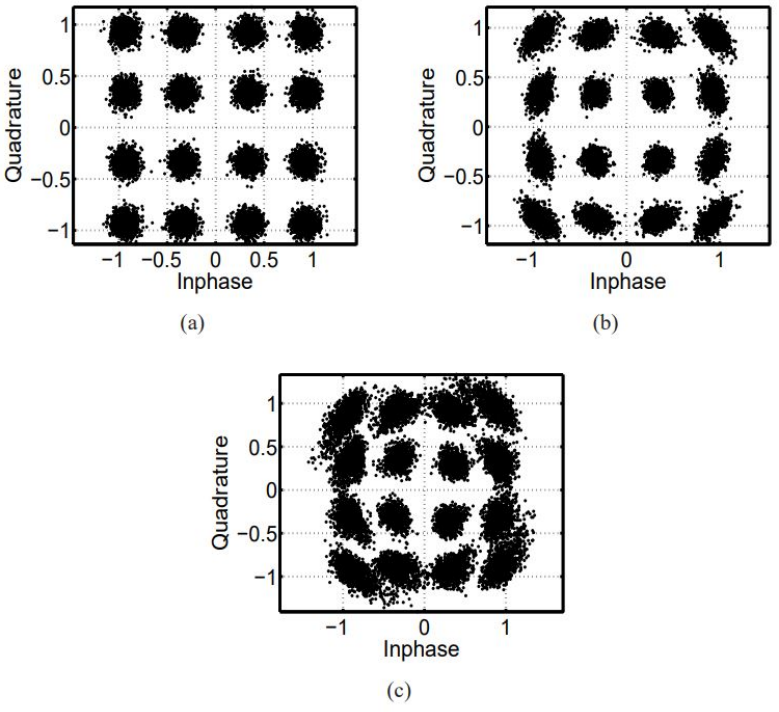

Greenland
Canada
United States
Mexico
Brazil
Bolivia
Chile
Argentina
Finland
Russia
Kazakhstan
Mongolia
China
Ukraine
Germany
Poland
Turkey
Iraq
Iran
Afghanistan
Pakistan
India
Thailand
Algeria
Libya
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
Kenya
DRC
Angola
Namibia
Botswana
Australia
New Zealand
North Pacific Ocean
North Pacific Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Last updated on December 11, 2019


Sequences of
Pulses (BITS)
Information In
(Voice, Data,
Video)
Encoder
Pulses of
Light
Light
Source
Fiber
Fiber
Decoder
Output Pulses of Current
Decoder
Information Out
(Voice, Data, Video)



Modulation format	NRZ	DQPSK	PM-QPSK	OFDM-QPSK
Symbol rate (GBaud)	112	56	28	28





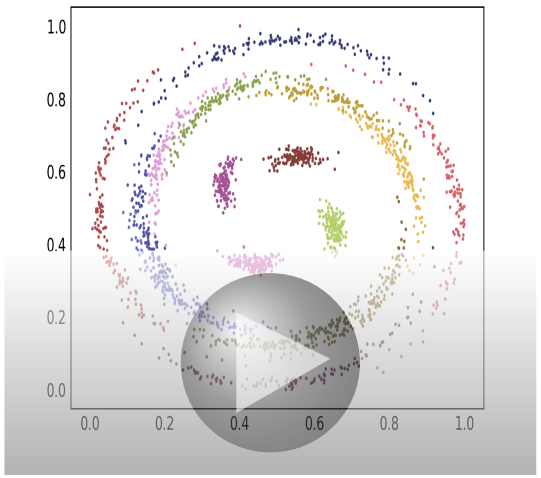


Fig. 2. Impact of different impairments on signal constellation for a 16-QAM signal. (a) Constellation of a signal dominated by additive noise. (b) Constellation of a signal dominated by phase noise. (c) Constellation of a signal dominated by non-linear phase noise.

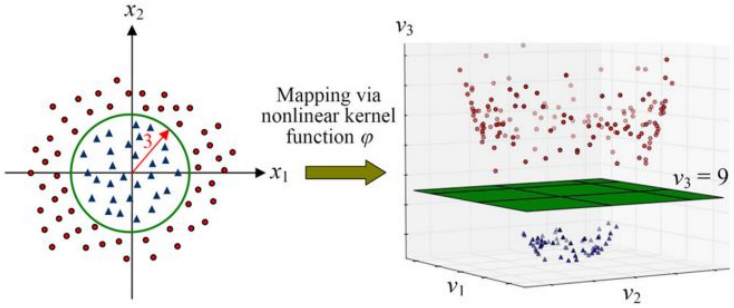


Fig. 9. Example showing how a linearly inseparable problem (in the original 2D data space) can undergo a nonlinear transformation and becomes a linearly separable one in the 3-dimensional (3D) feature space.

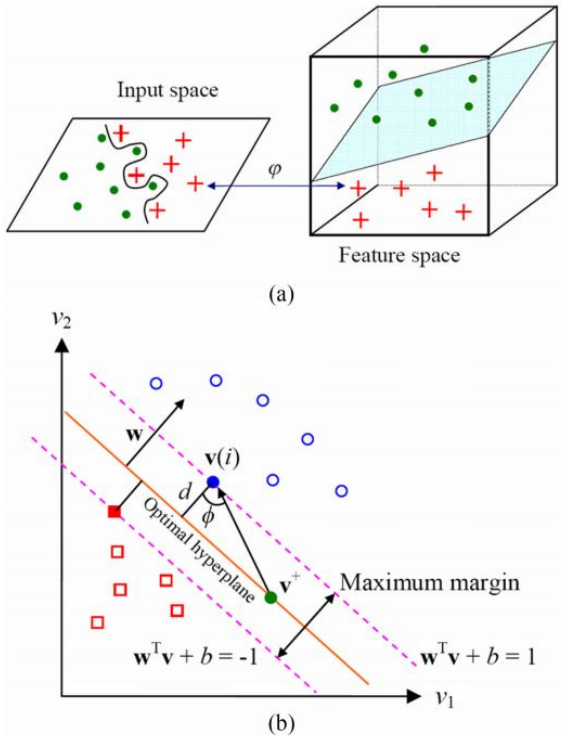
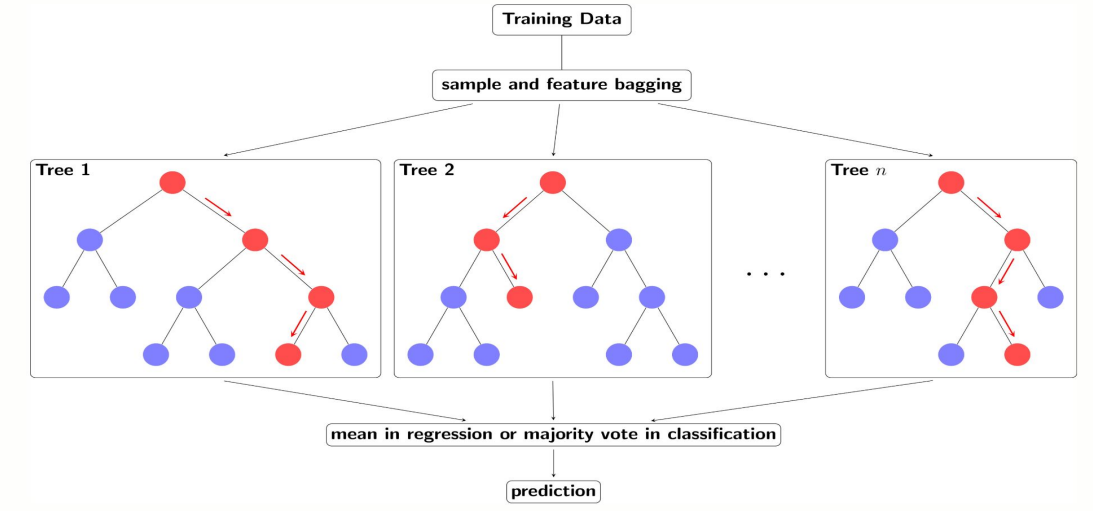
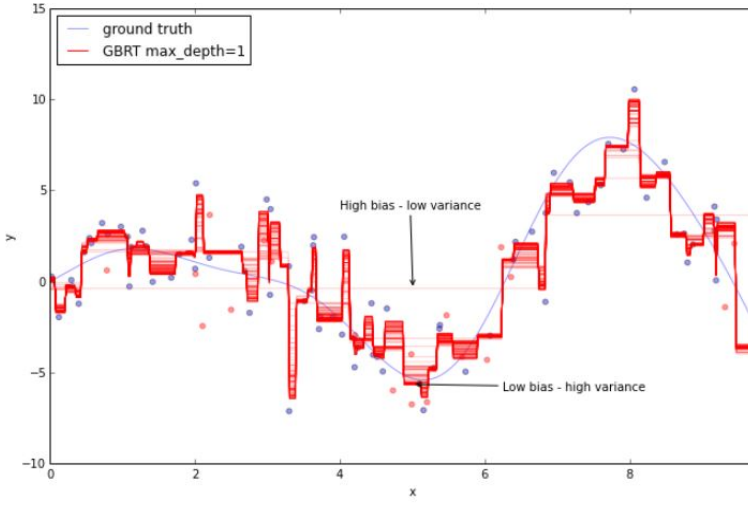
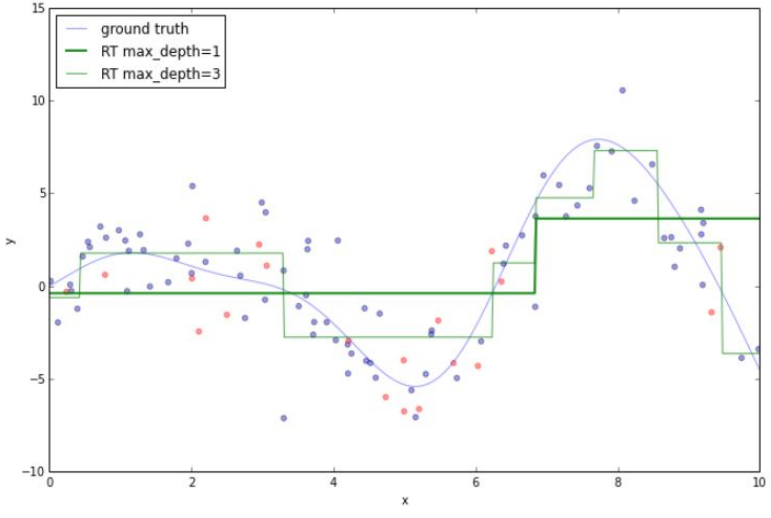
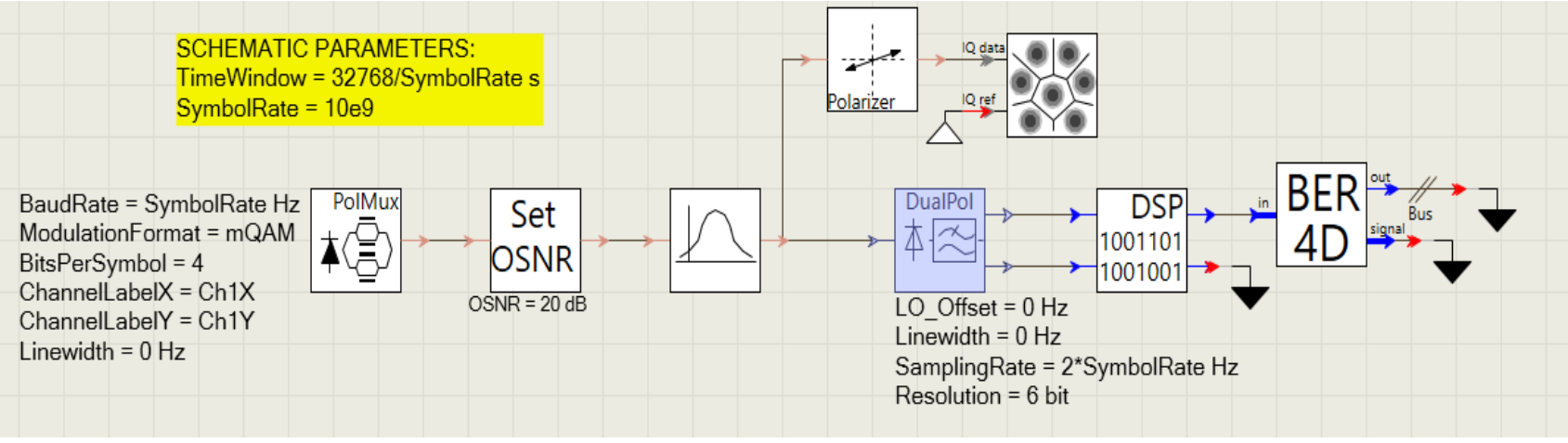


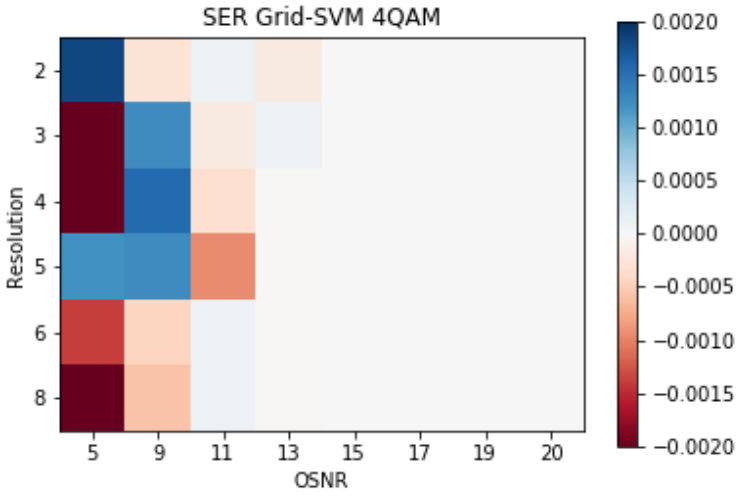
Fig. 10. (a) Maping from input space to a higher-dimensional feature space using a nonlinear kernel function φ. (b) Separation of two data classes in the feature space through an optimal hyperplane.

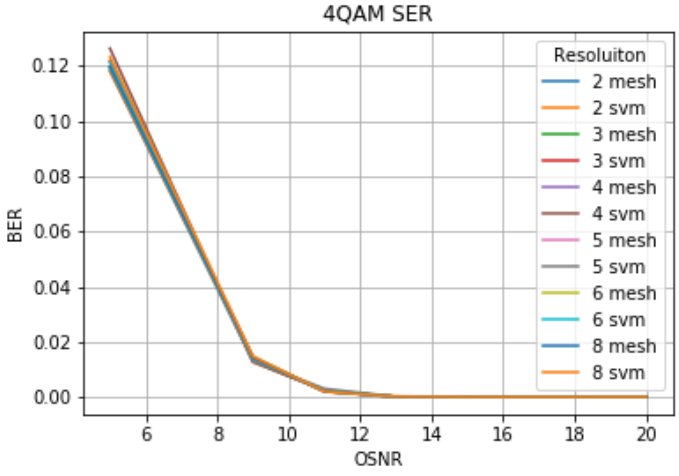

Training Data
sample and feature bagging
Tree 1
Tree 2
Tree n
. . .
mean in regression or majority vote in classification
prediction

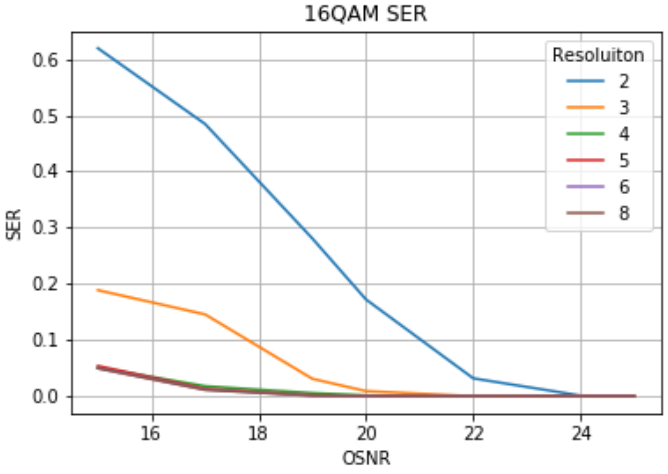

ground truth
GBRT max_depth=1
High bias - low variance
Low bias - high variance
x
y

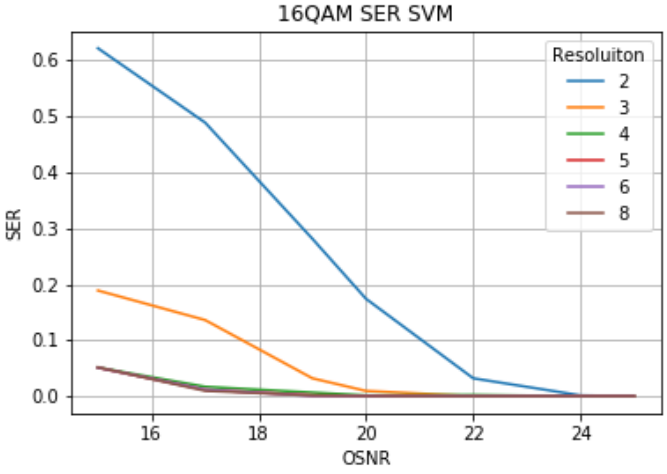

ground truth
RT max_depth=1
RT max_depth=3
x
y

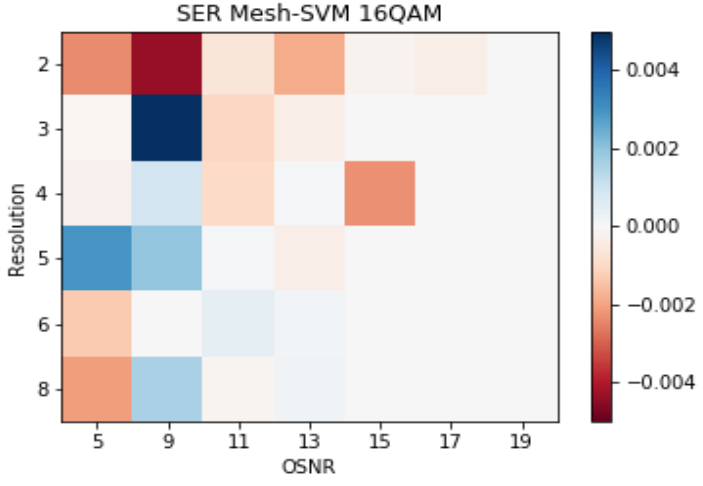

SCHEMATIC PARAMETERS:
TimeWindow = 32768/SymbolRate s
SymbolRate = 10e9
BaudRate = SymbolRate Hz
ModulationFormat = mQAM
BitsPerSymbol = 4
ChannelLabelX = Ch1X
ChannelLabelY = Ch1Y
Linewidth = 0 Hz
PolMux
Set
OSNR
OSNR = 20 dB
Polarizer
IQ data
IQ ref
DualPol
LO_Offset = 0 Hz
Linewidth = 0 Hz
SamplingRate = 2*SymbolRate Hz
Resolution = 6 bit
DSP
1001101
1001001
in
BER
4D
out
signal
Bus

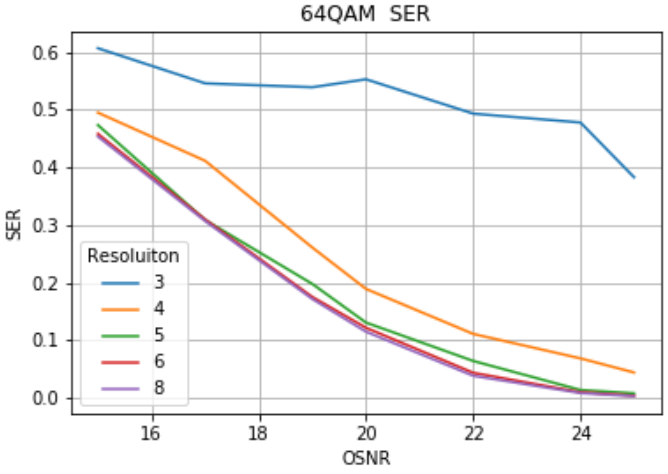

SER Grid-SVM 4QAM
Resolution
OSNR
2
3
4
5
6
8
5
9
11
13
15
17
19
20
0.0020
0.0015
0.0010
0.0005
0.0000
−0.0005
−0.0010
−0.0015
−0.0020

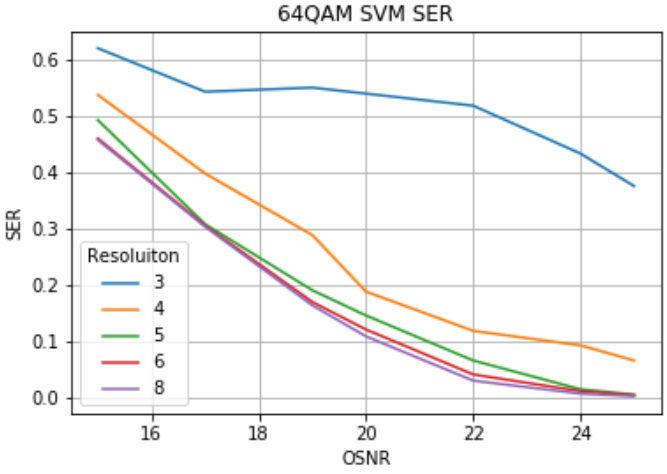

4QAM SER
BER
OSNR
0.12
0.10
0.08
0.06
0.04
0.02
0.00
6
8
10
12
14
16
18
20
Resoluiton
2 mesh
2 svm
3 mesh
3 svm
4 mesh
4 svm
5 mesh
5 svm
6 mesh
6 svm
8 mesh
8 svm

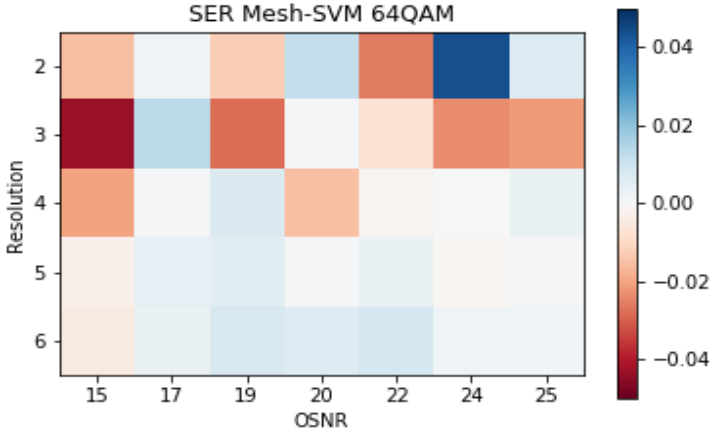

16QAM SER
Resoluiton
2
3
4
5
6
8
SER
OSNR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
16
18
20
22
24

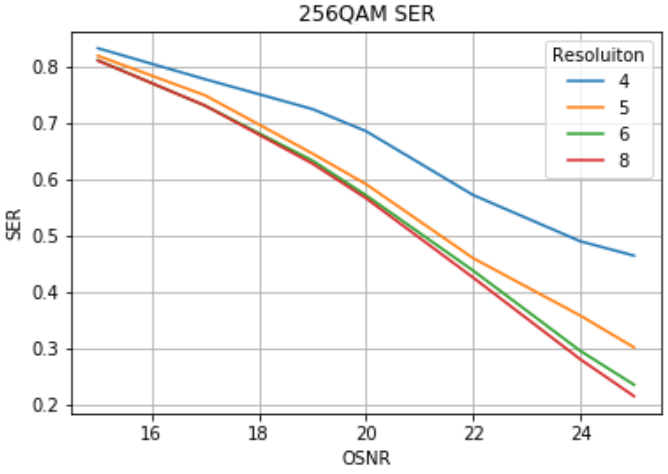

16QAM SER SVM
Resoluiton
2
3
4
5
6
8
SER
OSNR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
16
18
20
22
24

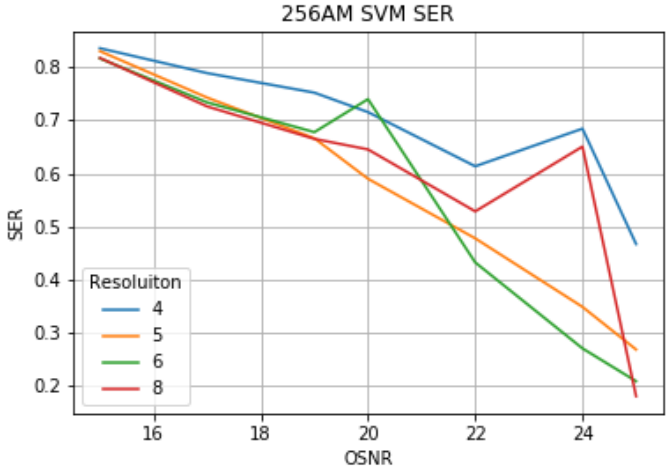

SER Mesh-SVM 16QAM
Resolution
OSNR
2
3
4
5
6
8
5
9
11
13
15
17
19
0.004
0.002
0.000
−0.002
−0.004

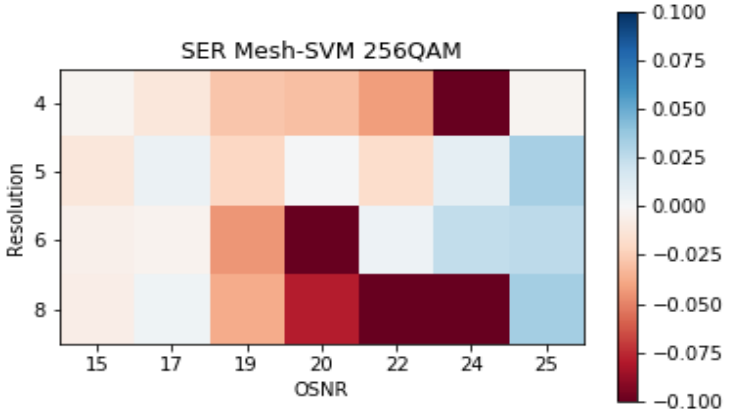

64QAM SER
SER
OSNR
Resoluiton
3
4
5
6
8


64QAM SVM SER
SER
OSNR
Resoluiton
3
4
5
6
8


SER Mesh-SVM 64QAM
Resolution
OSNR


256QAM SER
Resoluiton
4
5
6
8
SER
OSNR
0.8
0.7
0.6
0.5
0.4
0.3
0.2
16
18
20
22
24


256AM SVM SER
Resoluiton
4
5
6
8
SER
OSNR
0.8
0.7
0.6
0.5
0.4
0.3
0.2
16
18
20
22
24


SER Mesh-SVM 256QAM
Resolution
OSNR
4
5
6
8
15
17
19
20
22
24
25
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100

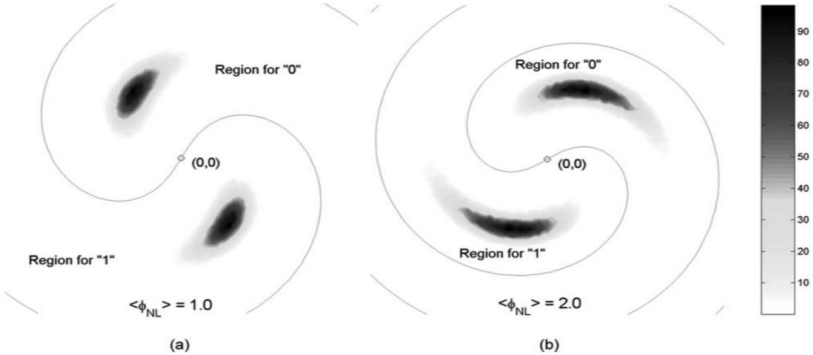


Fig. 2. Simulated distribution and decision regions of received signal with nonlinear phase noise for various mean nonlinear phase shifts: (a) $\langle \phi_{\mathrm{NL}} \rangle = 1$ rad and (b) $\langle \phi_{\mathrm{NL}} \rangle = 2$ rad.

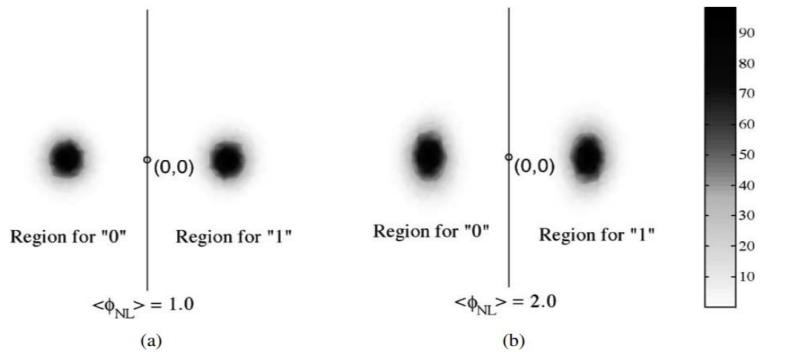
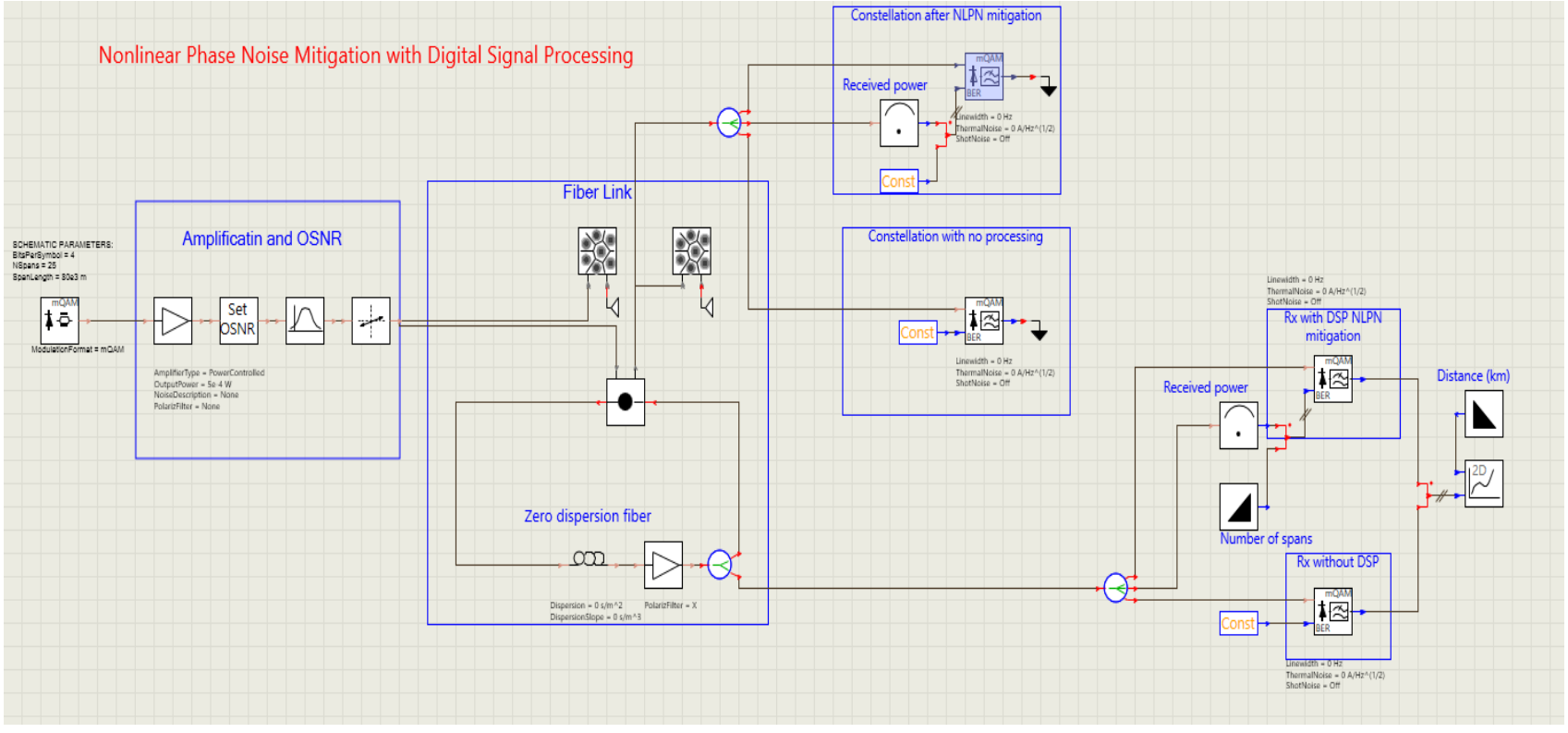
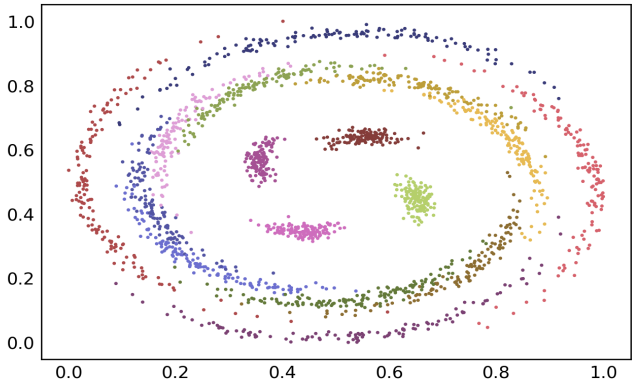
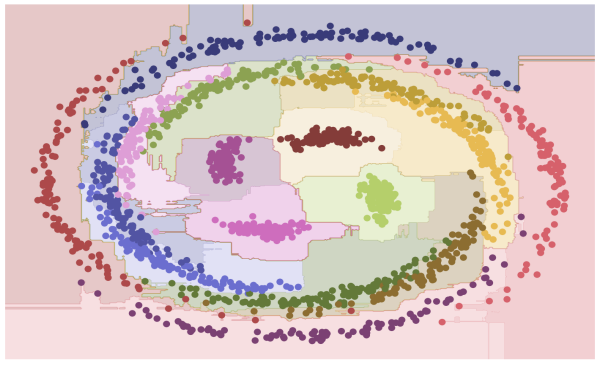
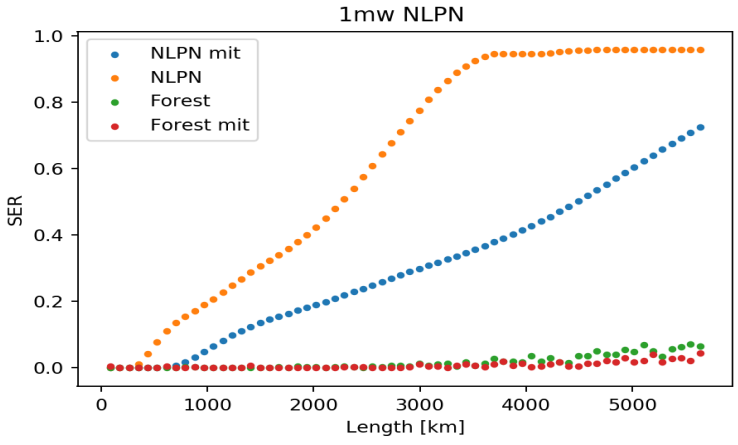


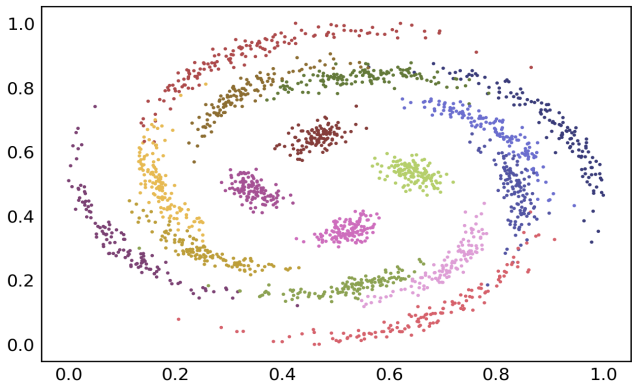
Fig. 3. Simulated distribution of corrected signal using optimal correction factor for various mean nonlinear phase shifts: (a) $\langle \phi_{\mathrm{NL}} \rangle = 1$ rad and (b) $\langle \phi_{\mathrm{NL}} \rangle = 2$ rad.

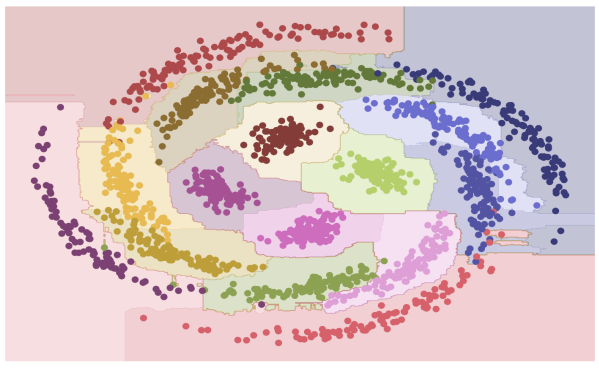

Nonlinear Phase Noise Mitigation with Digital Signal Processing
Constellation after NLPN mitigation
Received power
Const
Fiber Link
Amplificatin and OSNR
Constellation with no processing
Zero dispersion fiber
Rx with DSP NLPN mitigation
Distance (km)
Number of spans
Rx without DSP

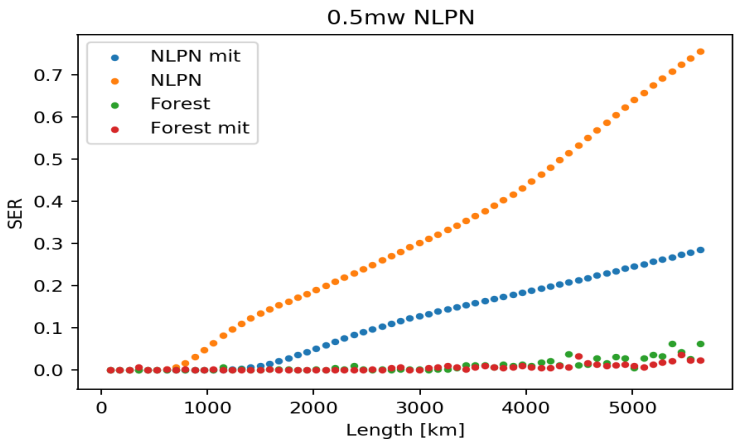

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

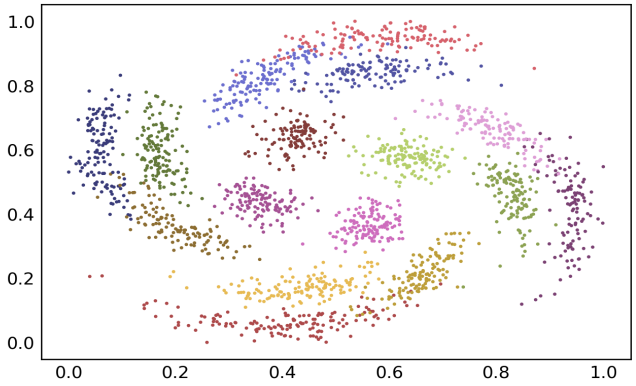


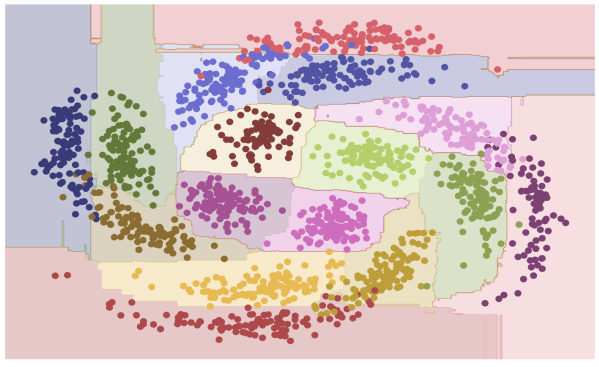

1mw NLPN
NLPN mit
NLPN
Forest
Forest mit
SER
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
Length [km]

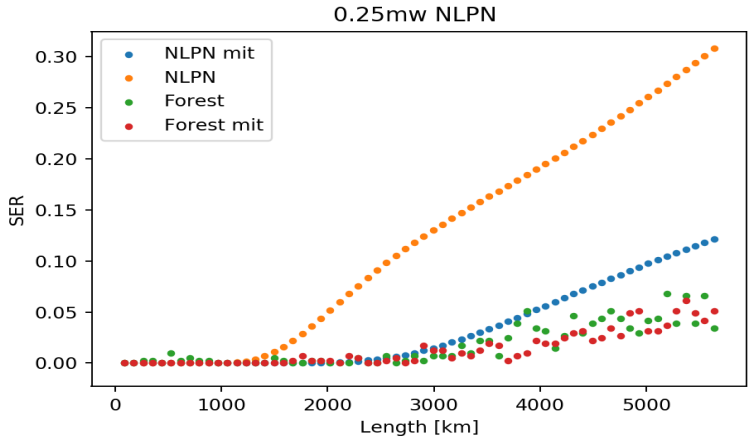

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

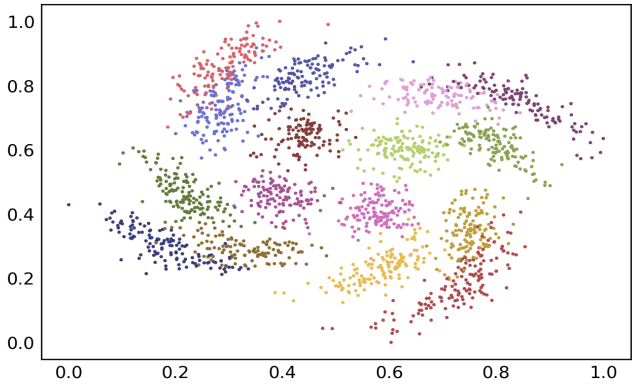


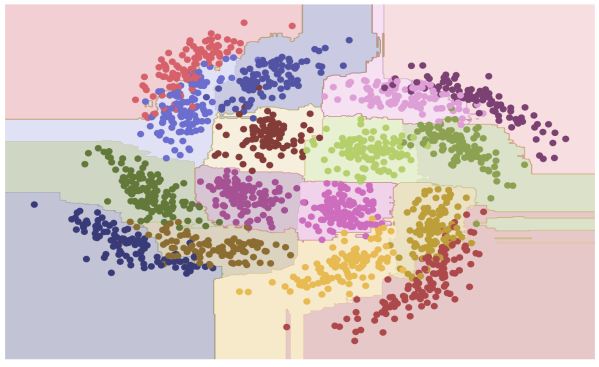

0.5mw NLPN
NLPN mit
NLPN
Forest
Forest mit
SER
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1000
2000
3000
4000
5000
Length [km]

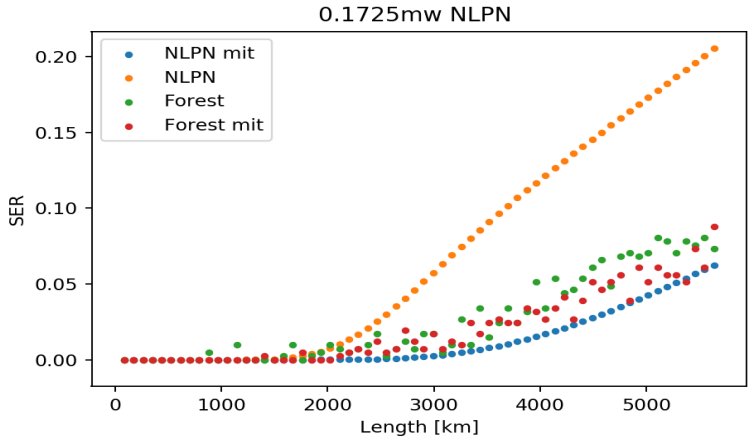

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

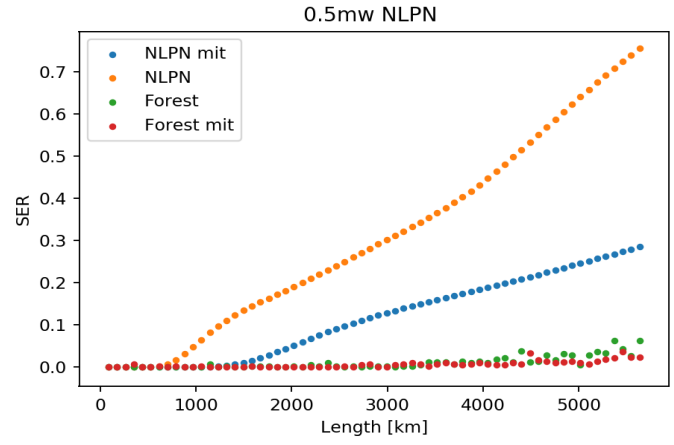


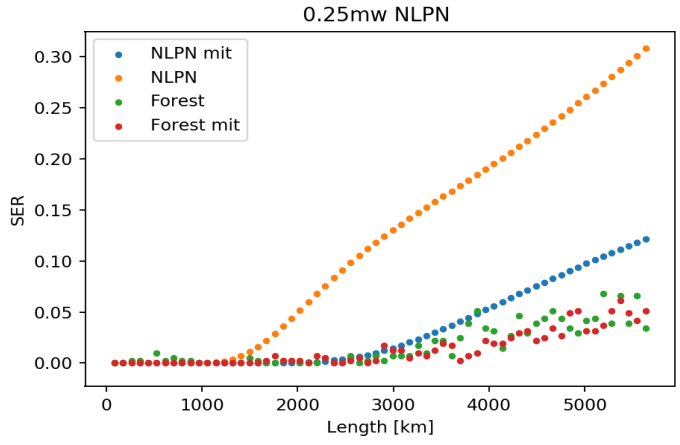

0.25mw NLPN
NLPN mit
NLPN
Forest
Forest mit
SER
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1000
2000
3000
4000
5000
Length [km]

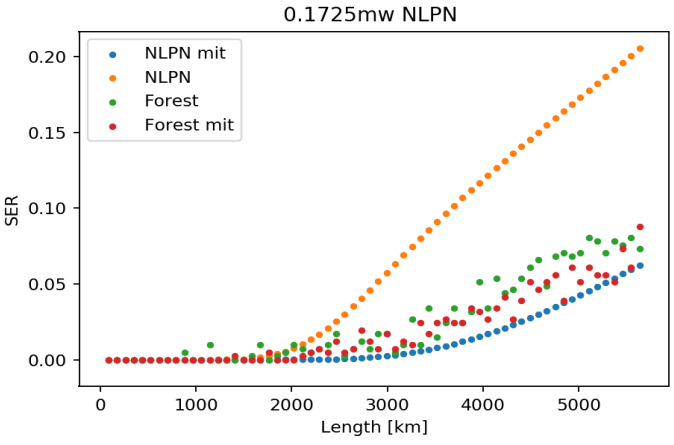

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

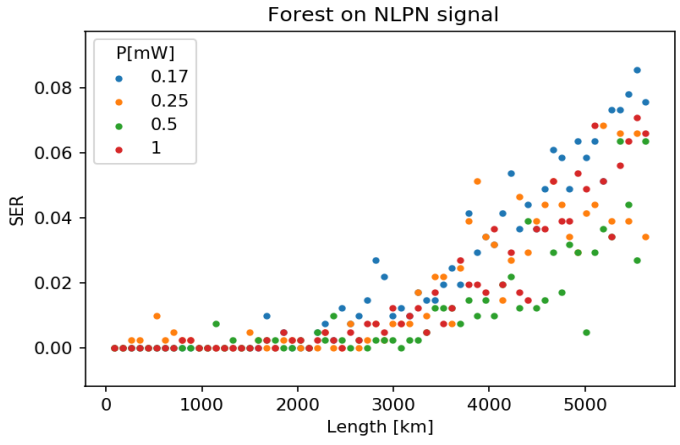



0.1725mw NLPN
NLPN mit
NLPN
Forest
Forest mit
SER
0.20
0.15
0.10
0.05
0.00
0
1000
2000
3000
4000
5000
Length [km]


0.5mw NLPN
NLPN mit
NLPN
Forest
Forest mit
SER
Length [km]


0.25mw NLPN
NLPN mit
NLPN
Forest
Forest mit
SER
Length [km]


0.1725mw NLPN
NLPN mit
NLPN
Forest
Forest mit
SER
Length [km]


Forest on NLPN signal
P[mW]
0.17
0.25
0.5
1
SER
Length [km]