

main

November 27, 2020

1 DNN-Detection-keras

1.1

DNN OFMD

1.2

DNN

1.3

- OS: Manjaro Linux x86_64
- Kernel: 5.4.80-1-MANJARO
- Python: 3.8.6
- Jupyter Notebook: 6.1.4
- Matplotlib: 3.3.3
- Numpy: 1.19.4
- Tensorflow: 2.3.1
- Keras: 2.4.0

1.4

run_all CP,P ,activation ,lr reslut [CP]-[P]-[activation]-[lr]

1.4.1

```
[1]: from tensorflow.keras import layers
from tensorflow.keras import models
from tensorflow.keras import optimizers
from generations import *
```

1.4.2

```
[2]: def init_model(activation):
    model = models.Sequential()
    model.add(
        layers.Dense(
```

```

        n_hidden_1, activation=activation,
        ↪input_shape=(payloadBits_per_OFDM * 2,)
    )
    model.add(layers.Dense(n_hidden_2, activation=activation))
    model.add(layers.Dense(n_hidden_3, activation=activation))
    model.add(layers.Dense(n_output, activation="sigmoid"))

    return model

```

1.4.3

```

[3]: def config_optimizer(model, lr):
    model.compile(
        optimizer=optimizers.RMSprop(lr=lr), loss="mse", metrics=[bit_err]
    )

    return model

```

1.4.4

```

[4]: def train_model(CP, P, pilotCarriers, dataCarriers, pilotValue, model):
    history = model.fit(
        training_gen(CP, P, pilotCarriers, dataCarriers, pilotValue, 1000, 20),
        steps_per_epoch=250,
        epochs=100,
        validation_data=validation_gen(
            CP, P, pilotCarriers, dataCarriers, pilotValue, 1000, 20
        ),
        validation_steps=1,
        verbose=2,
    )

    return model, history

```

1.4.5

```

[5]: def save_result(history, result_npz):
    loss = history.history["loss"]
    bit_err = history.history["bit_err"]
    val_loss = history.history["val_loss"]
    val_bit_err = history.history["val_bit_err"]

    np.savez(
        result_npz,
        loss=loss,

```

```

        bit_err=bit_err,
        val_loss=val_loss,
        val_bit_err=val_bit_err,
    )

```

1.4.6 SNR BER

```

[6]: def save_evaluate(
    CP, P, pilotCarriers, dataCarriers, pilotValue, model, result_npy
):
    BER = []
    for SNR in range(5, 30, 2):
        y = model.evaluate(
            validation_gen(
                CP, P, pilotCarriers, dataCarriers, pilotValue, 10000, SNR
            ),
            steps=1,
        ) # y=[loss_value, metrics_value]
        BER.append(y[1])

    np.save(result_npy, BER)

```

1.4.7 ber ber

```

[7]: import matplotlib.pyplot as plt

%matplotlib inline

def draw_training_ber(result_npz, suffix):
    datas = np.load(result_npz)
    loss = datas["loss"]
    bit_err = datas["bit_err"]
    val_loss = datas["val_loss"]
    val_bit_err = datas["val_bit_err"]

    epochs = range(1, len(loss) + 1)

    plt.semilogy(epochs, bit_err, "y", label="Training bit_err")
    plt.semilogy(epochs, val_bit_err, "b", label="Validation bit_err")
    plt.xlabel("epochs")
    plt.ylabel("BER")
    plt.title("Training and validation bit_err")
    plt.legend()
    plt.savefig(os.path.join("result", "bit_err" + suffix + ".jpg"))

    plt.figure()

```

```
return epochs, loss, val_loss
```

1.4.8

```
[8]: def draw_loss(epochs, loss, val_loss, suffix):
    plt.semilogy(epochs, loss, "y", label="Training loss")
    plt.semilogy(epochs, val_loss, "b", label="Validation loss")
    plt.xlabel("epochs")
    plt.ylabel("loss")
    plt.title("Training and validation loss")
    plt.legend()
    plt.savefig(os.path.join("result", "loss" + suffix + ".jpg"))

    plt.figure()
```

1.4.9 BER

```
[9]: def draw_learning_ber(result_npy, suffix):
    BER = np.load(result_npy)
    SNR = range(5, 30, 2)

    plt.semilogy(SNR, BER, "b", label="BER")
    plt.xlabel("SNR(dB)")
    plt.ylabel("BER")
    plt.title("BER of deep learning based approach")
    plt.legend()
    plt.savefig(os.path.join("result", "BER" + suffix + ".jpg"))

    plt.show()
```

```
[10]: def run_all(CP, P, activation, lr):
    suffix = "_" + "-".join([str(CP), str(P), activation, str(lr)])
    result_npz = os.path.join("result", "result" + suffix + ".npz")
    result_npy = "BER" + suffix + ".npy"

    pilotCarriers, dataCarriers = get_carriers(P)
    pilotValue = get_pilot_value(P)

    model = init_model(activation)
    model = config_optimizer(model, lr)
    model, history = train_model(
        CP, P, pilotCarriers, dataCarriers, pilotValue, model
    )

    save_result(history, result_npz)
    save_evaluate(
        CP, P, pilotCarriers, dataCarriers, pilotValue, model, result_npy
```

```
)

epochs, loss, val_loss = draw_training_ber(result_npz, suffix)
draw_loss(epochs, loss, val_loss, suffix)
draw_learning_ber(result_npy, suffix)
```

CP = 16, P = 64, activation = relu, lr = 0.001

```
[11]: run_all(16, 64, "relu", 0.001)
```

```
Epoch 1/100
250/250 - 54s - loss: 0.1173 - bit_err: 0.1631 - val_loss: 0.0395 - val_bit_err:
0.0454
Epoch 2/100
250/250 - 54s - loss: 0.0318 - bit_err: 0.0391 - val_loss: 0.0276 - val_bit_err:
0.0343
Epoch 3/100
250/250 - 53s - loss: 0.0193 - bit_err: 0.0247 - val_loss: 0.0166 - val_bit_err:
0.0222
Epoch 4/100
250/250 - 53s - loss: 0.0142 - bit_err: 0.0185 - val_loss: 0.0136 - val_bit_err:
0.0182
Epoch 5/100
250/250 - 46s - loss: 0.0113 - bit_err: 0.0150 - val_loss: 0.0090 - val_bit_err:
0.0125
Epoch 6/100
250/250 - 44s - loss: 0.0096 - bit_err: 0.0129 - val_loss: 0.0110 - val_bit_err:
0.0147
Epoch 7/100
250/250 - 46s - loss: 0.0085 - bit_err: 0.0116 - val_loss: 0.0076 - val_bit_err:
0.0098
Epoch 8/100
250/250 - 51s - loss: 0.0076 - bit_err: 0.0104 - val_loss: 0.0088 - val_bit_err:
0.0114
Epoch 9/100
250/250 - 55s - loss: 0.0070 - bit_err: 0.0096 - val_loss: 0.0068 - val_bit_err:
0.0089
Epoch 10/100
250/250 - 56s - loss: 0.0066 - bit_err: 0.0091 - val_loss: 0.0080 - val_bit_err:
0.0107
Epoch 11/100
250/250 - 58s - loss: 0.0064 - bit_err: 0.0087 - val_loss: 0.0057 - val_bit_err:
0.0077
Epoch 12/100
250/250 - 62s - loss: 0.0060 - bit_err: 0.0082 - val_loss: 0.0056 - val_bit_err:
0.0076
Epoch 13/100
250/250 - 70s - loss: 0.0058 - bit_err: 0.0080 - val_loss: 0.0058 - val_bit_err:
```

0.0079
Epoch 14/100
250/250 - 68s - loss: 0.0057 - bit_err: 0.0077 - val_loss: 0.0052 - val_bit_err:
0.0071
Epoch 15/100
250/250 - 67s - loss: 0.0056 - bit_err: 0.0075 - val_loss: 0.0059 - val_bit_err:
0.0080
Epoch 16/100
250/250 - 70s - loss: 0.0055 - bit_err: 0.0073 - val_loss: 0.0060 - val_bit_err:
0.0081
Epoch 17/100
250/250 - 76s - loss: 0.0054 - bit_err: 0.0072 - val_loss: 0.0056 - val_bit_err:
0.0074
Epoch 18/100
250/250 - 67s - loss: 0.0052 - bit_err: 0.0070 - val_loss: 0.0043 - val_bit_err:
0.0059
Epoch 19/100
250/250 - 65s - loss: 0.0053 - bit_err: 0.0070 - val_loss: 0.0045 - val_bit_err:
0.0060
Epoch 20/100
250/250 - 64s - loss: 0.0051 - bit_err: 0.0068 - val_loss: 0.0048 - val_bit_err:
0.0066
Epoch 21/100
250/250 - 69s - loss: 0.0051 - bit_err: 0.0068 - val_loss: 0.0047 - val_bit_err:
0.0064
Epoch 22/100
250/250 - 67s - loss: 0.0051 - bit_err: 0.0067 - val_loss: 0.0052 - val_bit_err:
0.0069
Epoch 23/100
250/250 - 67s - loss: 0.0050 - bit_err: 0.0066 - val_loss: 0.0054 - val_bit_err:
0.0073
Epoch 24/100
250/250 - 66s - loss: 0.0050 - bit_err: 0.0066 - val_loss: 0.0052 - val_bit_err:
0.0068
Epoch 25/100
250/250 - 87s - loss: 0.0049 - bit_err: 0.0065 - val_loss: 0.0054 - val_bit_err:
0.0068
Epoch 26/100
250/250 - 71s - loss: 0.0049 - bit_err: 0.0064 - val_loss: 0.0047 - val_bit_err:
0.0064
Epoch 27/100
250/250 - 61s - loss: 0.0049 - bit_err: 0.0064 - val_loss: 0.0049 - val_bit_err:
0.0064
Epoch 28/100
250/250 - 59s - loss: 0.0049 - bit_err: 0.0064 - val_loss: 0.0063 - val_bit_err:
0.0081
Epoch 29/100
250/250 - 55s - loss: 0.0049 - bit_err: 0.0064 - val_loss: 0.0046 - val_bit_err:

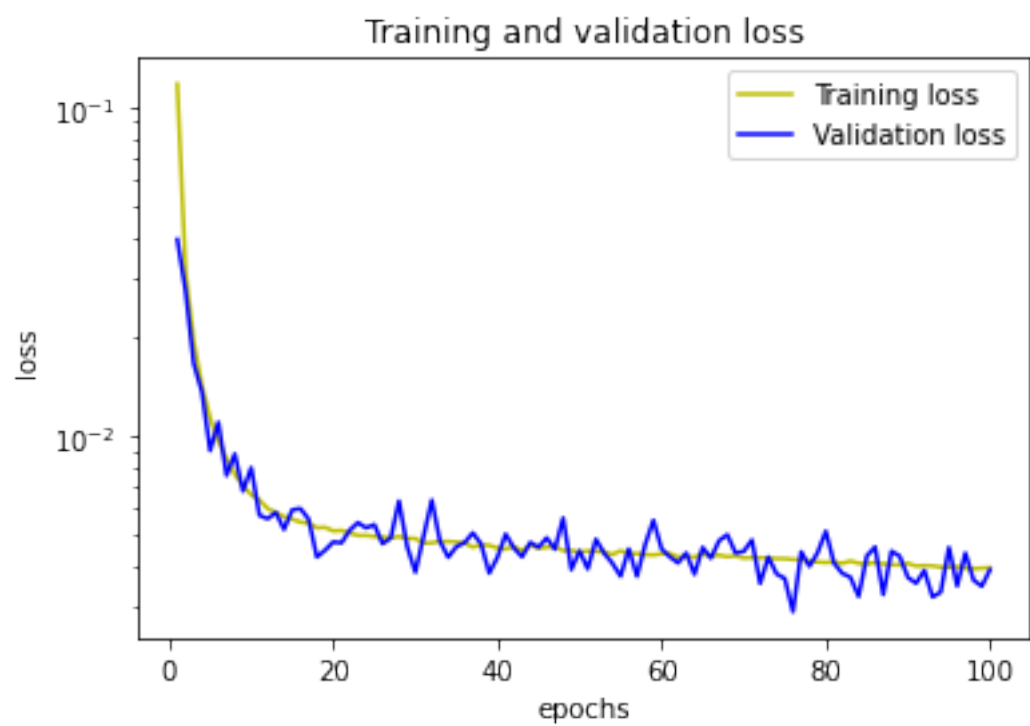
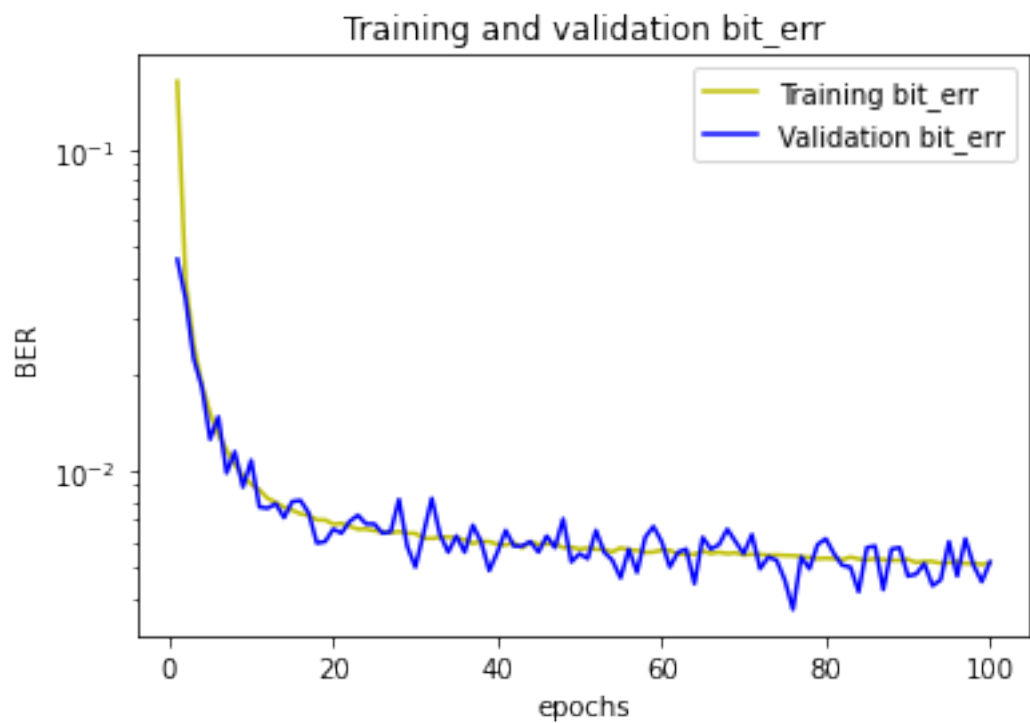
0.0058
Epoch 30/100
250/250 - 50s - loss: 0.0049 - bit_err: 0.0064 - val_loss: 0.0038 - val_bit_err:
0.0050
Epoch 31/100
250/250 - 49s - loss: 0.0047 - bit_err: 0.0061 - val_loss: 0.0049 - val_bit_err:
0.0064
Epoch 32/100
250/250 - 63s - loss: 0.0047 - bit_err: 0.0061 - val_loss: 0.0064 - val_bit_err:
0.0082
Epoch 33/100
250/250 - 49s - loss: 0.0048 - bit_err: 0.0062 - val_loss: 0.0048 - val_bit_err:
0.0063
Epoch 34/100
250/250 - 54s - loss: 0.0048 - bit_err: 0.0062 - val_loss: 0.0043 - val_bit_err:
0.0056
Epoch 35/100
250/250 - 49s - loss: 0.0047 - bit_err: 0.0062 - val_loss: 0.0046 - val_bit_err:
0.0063
Epoch 36/100
250/250 - 48s - loss: 0.0047 - bit_err: 0.0061 - val_loss: 0.0047 - val_bit_err:
0.0056
Epoch 37/100
250/250 - 48s - loss: 0.0046 - bit_err: 0.0059 - val_loss: 0.0051 - val_bit_err:
0.0067
Epoch 38/100
250/250 - 58s - loss: 0.0047 - bit_err: 0.0060 - val_loss: 0.0047 - val_bit_err:
0.0060
Epoch 39/100
250/250 - 54s - loss: 0.0046 - bit_err: 0.0060 - val_loss: 0.0038 - val_bit_err:
0.0049
Epoch 40/100
250/250 - 50s - loss: 0.0046 - bit_err: 0.0059 - val_loss: 0.0043 - val_bit_err:
0.0056
Epoch 41/100
250/250 - 48s - loss: 0.0045 - bit_err: 0.0059 - val_loss: 0.0050 - val_bit_err:
0.0065
Epoch 42/100
250/250 - 48s - loss: 0.0046 - bit_err: 0.0059 - val_loss: 0.0046 - val_bit_err:
0.0058
Epoch 43/100
250/250 - 47s - loss: 0.0045 - bit_err: 0.0057 - val_loss: 0.0043 - val_bit_err:
0.0058
Epoch 44/100
250/250 - 48s - loss: 0.0046 - bit_err: 0.0060 - val_loss: 0.0047 - val_bit_err:
0.0060
Epoch 45/100
250/250 - 57s - loss: 0.0045 - bit_err: 0.0059 - val_loss: 0.0046 - val_bit_err:

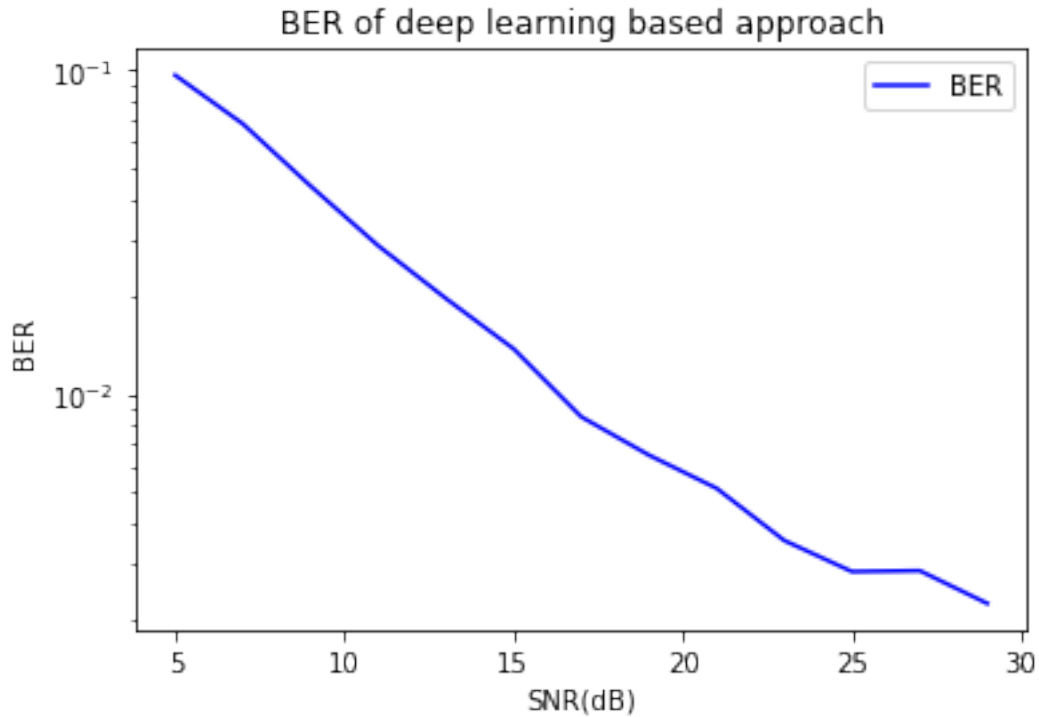
0.0056
Epoch 46/100
250/250 - 53s - loss: 0.0046 - bit_err: 0.0059 - val_loss: 0.0049 - val_bit_err:
0.0063
Epoch 47/100
250/250 - 47s - loss: 0.0046 - bit_err: 0.0059 - val_loss: 0.0045 - val_bit_err:
0.0058
Epoch 48/100
250/250 - 48s - loss: 0.0045 - bit_err: 0.0057 - val_loss: 0.0056 - val_bit_err:
0.0071
Epoch 49/100
250/250 - 48s - loss: 0.0045 - bit_err: 0.0058 - val_loss: 0.0039 - val_bit_err:
0.0052
Epoch 50/100
250/250 - 60s - loss: 0.0044 - bit_err: 0.0057 - val_loss: 0.0045 - val_bit_err:
0.0055
Epoch 51/100
250/250 - 69s - loss: 0.0045 - bit_err: 0.0057 - val_loss: 0.0039 - val_bit_err:
0.0053
Epoch 52/100
250/250 - 60s - loss: 0.0044 - bit_err: 0.0057 - val_loss: 0.0048 - val_bit_err:
0.0065
Epoch 53/100
250/250 - 58s - loss: 0.0044 - bit_err: 0.0057 - val_loss: 0.0044 - val_bit_err:
0.0056
Epoch 54/100
250/250 - 56s - loss: 0.0043 - bit_err: 0.0056 - val_loss: 0.0041 - val_bit_err:
0.0052
Epoch 55/100
250/250 - 55s - loss: 0.0045 - bit_err: 0.0057 - val_loss: 0.0037 - val_bit_err:
0.0046
Epoch 56/100
250/250 - 63s - loss: 0.0044 - bit_err: 0.0057 - val_loss: 0.0045 - val_bit_err:
0.0057
Epoch 57/100
250/250 - 62s - loss: 0.0044 - bit_err: 0.0056 - val_loss: 0.0037 - val_bit_err:
0.0048
Epoch 58/100
250/250 - 65s - loss: 0.0043 - bit_err: 0.0056 - val_loss: 0.0047 - val_bit_err:
0.0062
Epoch 59/100
250/250 - 57s - loss: 0.0043 - bit_err: 0.0056 - val_loss: 0.0055 - val_bit_err:
0.0067
Epoch 60/100
250/250 - 64s - loss: 0.0044 - bit_err: 0.0056 - val_loss: 0.0045 - val_bit_err:
0.0060
Epoch 61/100
250/250 - 54s - loss: 0.0044 - bit_err: 0.0056 - val_loss: 0.0043 - val_bit_err:

0.0050
Epoch 62/100
250/250 - 54s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0041 - val_bit_err:
0.0056
Epoch 63/100
250/250 - 59s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0044 - val_bit_err:
0.0057
Epoch 64/100
250/250 - 51s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0038 - val_bit_err:
0.0044
Epoch 65/100
250/250 - 62s - loss: 0.0044 - bit_err: 0.0056 - val_loss: 0.0046 - val_bit_err:
0.0062
Epoch 66/100
250/250 - 60s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0042 - val_bit_err:
0.0057
Epoch 67/100
250/250 - 58s - loss: 0.0043 - bit_err: 0.0056 - val_loss: 0.0048 - val_bit_err:
0.0059
Epoch 68/100
250/250 - 60s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0050 - val_bit_err:
0.0066
Epoch 69/100
250/250 - 69s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0044 - val_bit_err:
0.0060
Epoch 70/100
250/250 - 56s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0044 - val_bit_err:
0.0055
Epoch 71/100
250/250 - 55s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0048 - val_bit_err:
0.0063
Epoch 72/100
250/250 - 68s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0036 - val_bit_err:
0.0049
Epoch 73/100
250/250 - 62s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0043 - val_bit_err:
0.0054
Epoch 74/100
250/250 - 55s - loss: 0.0042 - bit_err: 0.0055 - val_loss: 0.0038 - val_bit_err:
0.0052
Epoch 75/100
250/250 - 59s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0037 - val_bit_err:
0.0046
Epoch 76/100
250/250 - 62s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0029 - val_bit_err:
0.0037
Epoch 77/100
250/250 - 50s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0044 - val_bit_err:

0.0054
 Epoch 78/100
 250/250 - 58s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0040 - val_bit_err:
 0.0049
 Epoch 79/100
 250/250 - 64s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0044 - val_bit_err:
 0.0059
 Epoch 80/100
 250/250 - 57s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0051 - val_bit_err:
 0.0061
 Epoch 81/100
 250/250 - 63s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0041 - val_bit_err:
 0.0055
 Epoch 82/100
 250/250 - 56s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0038 - val_bit_err:
 0.0051
 Epoch 83/100
 250/250 - 57s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0037 - val_bit_err:
 0.0050
 Epoch 84/100
 250/250 - 62s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0032 - val_bit_err:
 0.0042
 Epoch 85/100
 250/250 - 61s - loss: 0.0041 - bit_err: 0.0052 - val_loss: 0.0043 - val_bit_err:
 0.0058
 Epoch 86/100
 250/250 - 55s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0046 - val_bit_err:
 0.0058
 Epoch 87/100
 250/250 - 59s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0033 - val_bit_err:
 0.0042
 Epoch 88/100
 250/250 - 62s - loss: 0.0040 - bit_err: 0.0053 - val_loss: 0.0045 - val_bit_err:
 0.0057
 Epoch 89/100
 250/250 - 55s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0043 - val_bit_err:
 0.0058
 Epoch 90/100
 250/250 - 61s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0037 - val_bit_err:
 0.0047
 Epoch 91/100
 250/250 - 64s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0036 - val_bit_err:
 0.0048
 Epoch 92/100
 250/250 - 55s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0039 - val_bit_err:
 0.0051
 Epoch 93/100
 250/250 - 61s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0032 - val_bit_err:

0.0044
 Epoch 94/100
 250/250 - 59s - loss: 0.0040 - bit_err: 0.0051 - val_loss: 0.0033 - val_bit_err:
 0.0046
 Epoch 95/100
 250/250 - 63s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0046 - val_bit_err:
 0.0060
 Epoch 96/100
 250/250 - 86s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0035 - val_bit_err:
 0.0047
 Epoch 97/100
 250/250 - 85s - loss: 0.0040 - bit_err: 0.0051 - val_loss: 0.0044 - val_bit_err:
 0.0061
 Epoch 98/100
 250/250 - 110s - loss: 0.0039 - bit_err: 0.0051 - val_loss: 0.0036 -
 val_bit_err: 0.0051
 Epoch 99/100
 250/250 - 103s - loss: 0.0040 - bit_err: 0.0051 - val_loss: 0.0035 -
 val_bit_err: 0.0045
 Epoch 100/100
 250/250 - 79s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0039 - val_bit_err:
 0.0052
 1/1 [=====] - 0s 3ms/step - loss: 0.0882 - bit_err:
 0.0963
 1/1 [=====] - 0s 4ms/step - loss: 0.0612 - bit_err:
 0.0681
 1/1 [=====] - 0s 2ms/step - loss: 0.0389 - bit_err:
 0.0438
 1/1 [=====] - 0s 3ms/step - loss: 0.0248 - bit_err:
 0.0287
 1/1 [=====] - 0s 2ms/step - loss: 0.0167 - bit_err:
 0.0197
 1/1 [=====] - 0s 1ms/step - loss: 0.0114 - bit_err:
 0.0138
 1/1 [=====] - 0s 3ms/step - loss: 0.0068 - bit_err:
 0.0085
 1/1 [=====] - 0s 1ms/step - loss: 0.0050 - bit_err:
 0.0065
 1/1 [=====] - 0s 2ms/step - loss: 0.0039 - bit_err:
 0.0051
 1/1 [=====] - 0s 4ms/step - loss: 0.0027 - bit_err:
 0.0035
 1/1 [=====] - 0s 2ms/step - loss: 0.0022 - bit_err:
 0.0028
 1/1 [=====] - 0s 2ms/step - loss: 0.0020 - bit_err:
 0.0029
 1/1 [=====] - 0s 2ms/step - loss: 0.0017 - bit_err:
 0.0023





CP = 16, P = 8, activation = relu, lr = 0.001

```
[12]: run_all(16, 8, "relu", 0.001)
```

Epoch 1/100

250/250 - 46s - loss: 0.1521 - bit_err: 0.2332 - val_loss: 0.0633 - val_bit_err: 0.0798

Epoch 2/100

250/250 - 45s - loss: 0.0473 - bit_err: 0.0619 - val_loss: 0.0401 - val_bit_err: 0.0552

Epoch 3/100

250/250 - 43s - loss: 0.0343 - bit_err: 0.0468 - val_loss: 0.0283 - val_bit_err: 0.0381

Epoch 4/100

250/250 - 43s - loss: 0.0252 - bit_err: 0.0342 - val_loss: 0.0215 - val_bit_err: 0.0290

Epoch 5/100

250/250 - 43s - loss: 0.0198 - bit_err: 0.0271 - val_loss: 0.0202 - val_bit_err: 0.0279

Epoch 6/100

250/250 - 43s - loss: 0.0168 - bit_err: 0.0230 - val_loss: 0.0167 - val_bit_err: 0.0229

Epoch 7/100

250/250 - 43s - loss: 0.0151 - bit_err: 0.0208 - val_loss: 0.0143 - val_bit_err:

0.0194
Epoch 8/100
250/250 - 43s - loss: 0.0139 - bit_err: 0.0191 - val_loss: 0.0144 - val_bit_err:
0.0203
Epoch 9/100
250/250 - 43s - loss: 0.0132 - bit_err: 0.0182 - val_loss: 0.0120 - val_bit_err:
0.0174
Epoch 10/100
250/250 - 43s - loss: 0.0127 - bit_err: 0.0174 - val_loss: 0.0111 - val_bit_err:
0.0155
Epoch 11/100
250/250 - 43s - loss: 0.0122 - bit_err: 0.0167 - val_loss: 0.0123 - val_bit_err:
0.0170
Epoch 12/100
250/250 - 43s - loss: 0.0117 - bit_err: 0.0161 - val_loss: 0.0116 - val_bit_err:
0.0160
Epoch 13/100
250/250 - 43s - loss: 0.0116 - bit_err: 0.0158 - val_loss: 0.0114 - val_bit_err:
0.0159
Epoch 14/100
250/250 - 43s - loss: 0.0111 - bit_err: 0.0152 - val_loss: 0.0133 - val_bit_err:
0.0179
Epoch 15/100
250/250 - 43s - loss: 0.0110 - bit_err: 0.0150 - val_loss: 0.0100 - val_bit_err:
0.0142
Epoch 16/100
250/250 - 44s - loss: 0.0108 - bit_err: 0.0147 - val_loss: 0.0105 - val_bit_err:
0.0144
Epoch 17/100
250/250 - 44s - loss: 0.0107 - bit_err: 0.0145 - val_loss: 0.0100 - val_bit_err:
0.0136
Epoch 18/100
250/250 - 44s - loss: 0.0105 - bit_err: 0.0143 - val_loss: 0.0098 - val_bit_err:
0.0129
Epoch 19/100
250/250 - 44s - loss: 0.0104 - bit_err: 0.0141 - val_loss: 0.0126 - val_bit_err:
0.0171
Epoch 20/100
250/250 - 44s - loss: 0.0103 - bit_err: 0.0140 - val_loss: 0.0093 - val_bit_err:
0.0126
Epoch 21/100
250/250 - 45s - loss: 0.0101 - bit_err: 0.0138 - val_loss: 0.0118 - val_bit_err:
0.0163
Epoch 22/100
250/250 - 45s - loss: 0.0102 - bit_err: 0.0138 - val_loss: 0.0108 - val_bit_err:
0.0148
Epoch 23/100
250/250 - 46s - loss: 0.0100 - bit_err: 0.0136 - val_loss: 0.0102 - val_bit_err:

0.0142
Epoch 24/100
250/250 - 46s - loss: 0.0099 - bit_err: 0.0135 - val_loss: 0.0130 - val_bit_err:
0.0177
Epoch 25/100
250/250 - 48s - loss: 0.0097 - bit_err: 0.0131 - val_loss: 0.0091 - val_bit_err:
0.0123
Epoch 26/100
250/250 - 48s - loss: 0.0098 - bit_err: 0.0132 - val_loss: 0.0118 - val_bit_err:
0.0159
Epoch 27/100
250/250 - 47s - loss: 0.0097 - bit_err: 0.0130 - val_loss: 0.0099 - val_bit_err:
0.0136
Epoch 28/100
250/250 - 48s - loss: 0.0097 - bit_err: 0.0131 - val_loss: 0.0095 - val_bit_err:
0.0135
Epoch 29/100
250/250 - 47s - loss: 0.0096 - bit_err: 0.0130 - val_loss: 0.0089 - val_bit_err:
0.0116
Epoch 30/100
250/250 - 47s - loss: 0.0095 - bit_err: 0.0128 - val_loss: 0.0095 - val_bit_err:
0.0132
Epoch 31/100
250/250 - 47s - loss: 0.0095 - bit_err: 0.0128 - val_loss: 0.0072 - val_bit_err:
0.0099
Epoch 32/100
250/250 - 48s - loss: 0.0095 - bit_err: 0.0128 - val_loss: 0.0096 - val_bit_err:
0.0125
Epoch 33/100
250/250 - 47s - loss: 0.0095 - bit_err: 0.0128 - val_loss: 0.0108 - val_bit_err:
0.0140
Epoch 34/100
250/250 - 47s - loss: 0.0094 - bit_err: 0.0128 - val_loss: 0.0085 - val_bit_err:
0.0112
Epoch 35/100
250/250 - 47s - loss: 0.0092 - bit_err: 0.0125 - val_loss: 0.0095 - val_bit_err:
0.0134
Epoch 36/100
250/250 - 47s - loss: 0.0093 - bit_err: 0.0125 - val_loss: 0.0095 - val_bit_err:
0.0134
Epoch 37/100
250/250 - 48s - loss: 0.0093 - bit_err: 0.0126 - val_loss: 0.0088 - val_bit_err:
0.0121
Epoch 38/100
250/250 - 47s - loss: 0.0092 - bit_err: 0.0124 - val_loss: 0.0093 - val_bit_err:
0.0126
Epoch 39/100
250/250 - 47s - loss: 0.0090 - bit_err: 0.0122 - val_loss: 0.0100 - val_bit_err:

0.0134
Epoch 40/100
250/250 - 47s - loss: 0.0091 - bit_err: 0.0123 - val_loss: 0.0092 - val_bit_err:
0.0126
Epoch 41/100
250/250 - 47s - loss: 0.0091 - bit_err: 0.0123 - val_loss: 0.0089 - val_bit_err:
0.0115
Epoch 42/100
250/250 - 47s - loss: 0.0090 - bit_err: 0.0121 - val_loss: 0.0095 - val_bit_err:
0.0132
Epoch 43/100
250/250 - 47s - loss: 0.0090 - bit_err: 0.0121 - val_loss: 0.0071 - val_bit_err:
0.0093
Epoch 44/100
250/250 - 48s - loss: 0.0089 - bit_err: 0.0120 - val_loss: 0.0074 - val_bit_err:
0.0105
Epoch 45/100
250/250 - 47s - loss: 0.0088 - bit_err: 0.0120 - val_loss: 0.0088 - val_bit_err:
0.0114
Epoch 46/100
250/250 - 48s - loss: 0.0089 - bit_err: 0.0120 - val_loss: 0.0094 - val_bit_err:
0.0129
Epoch 47/100
250/250 - 47s - loss: 0.0088 - bit_err: 0.0119 - val_loss: 0.0080 - val_bit_err:
0.0108
Epoch 48/100
250/250 - 47s - loss: 0.0087 - bit_err: 0.0118 - val_loss: 0.0088 - val_bit_err:
0.0120
Epoch 49/100
250/250 - 48s - loss: 0.0086 - bit_err: 0.0116 - val_loss: 0.0075 - val_bit_err:
0.0102
Epoch 50/100
250/250 - 47s - loss: 0.0086 - bit_err: 0.0117 - val_loss: 0.0108 - val_bit_err:
0.0149
Epoch 51/100
250/250 - 48s - loss: 0.0085 - bit_err: 0.0115 - val_loss: 0.0065 - val_bit_err:
0.0086
Epoch 52/100
250/250 - 48s - loss: 0.0084 - bit_err: 0.0114 - val_loss: 0.0103 - val_bit_err:
0.0139
Epoch 53/100
250/250 - 47s - loss: 0.0085 - bit_err: 0.0115 - val_loss: 0.0093 - val_bit_err:
0.0130
Epoch 54/100
250/250 - 48s - loss: 0.0084 - bit_err: 0.0114 - val_loss: 0.0088 - val_bit_err:
0.0119
Epoch 55/100
250/250 - 47s - loss: 0.0084 - bit_err: 0.0114 - val_loss: 0.0081 - val_bit_err:

0.0107
Epoch 56/100
250/250 - 48s - loss: 0.0084 - bit_err: 0.0113 - val_loss: 0.0066 - val_bit_err:
0.0091
Epoch 57/100
250/250 - 47s - loss: 0.0082 - bit_err: 0.0112 - val_loss: 0.0090 - val_bit_err:
0.0119
Epoch 58/100
250/250 - 47s - loss: 0.0082 - bit_err: 0.0111 - val_loss: 0.0079 - val_bit_err:
0.0105
Epoch 59/100
250/250 - 47s - loss: 0.0082 - bit_err: 0.0111 - val_loss: 0.0073 - val_bit_err:
0.0102
Epoch 60/100
250/250 - 47s - loss: 0.0081 - bit_err: 0.0109 - val_loss: 0.0098 - val_bit_err:
0.0131
Epoch 61/100
250/250 - 47s - loss: 0.0080 - bit_err: 0.0108 - val_loss: 0.0075 - val_bit_err:
0.0102
Epoch 62/100
250/250 - 47s - loss: 0.0080 - bit_err: 0.0109 - val_loss: 0.0096 - val_bit_err:
0.0128
Epoch 63/100
250/250 - 47s - loss: 0.0078 - bit_err: 0.0106 - val_loss: 0.0071 - val_bit_err:
0.0096
Epoch 64/100
250/250 - 47s - loss: 0.0078 - bit_err: 0.0106 - val_loss: 0.0091 - val_bit_err:
0.0126
Epoch 65/100
250/250 - 47s - loss: 0.0078 - bit_err: 0.0106 - val_loss: 0.0078 - val_bit_err:
0.0105
Epoch 66/100
250/250 - 47s - loss: 0.0078 - bit_err: 0.0105 - val_loss: 0.0098 - val_bit_err:
0.0129
Epoch 67/100
250/250 - 47s - loss: 0.0079 - bit_err: 0.0108 - val_loss: 0.0063 - val_bit_err:
0.0087
Epoch 68/100
250/250 - 48s - loss: 0.0078 - bit_err: 0.0106 - val_loss: 0.0079 - val_bit_err:
0.0104
Epoch 69/100
250/250 - 47s - loss: 0.0077 - bit_err: 0.0105 - val_loss: 0.0089 - val_bit_err:
0.0115
Epoch 70/100
250/250 - 48s - loss: 0.0077 - bit_err: 0.0104 - val_loss: 0.0077 - val_bit_err:
0.0104
Epoch 71/100
250/250 - 47s - loss: 0.0077 - bit_err: 0.0104 - val_loss: 0.0087 - val_bit_err:

0.0113
Epoch 72/100
250/250 - 48s - loss: 0.0076 - bit_err: 0.0103 - val_loss: 0.0080 - val_bit_err:
0.0108
Epoch 73/100
250/250 - 47s - loss: 0.0076 - bit_err: 0.0102 - val_loss: 0.0086 - val_bit_err:
0.0116
Epoch 74/100
250/250 - 47s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0074 - val_bit_err:
0.0101
Epoch 75/100
250/250 - 47s - loss: 0.0076 - bit_err: 0.0103 - val_loss: 0.0067 - val_bit_err:
0.0092
Epoch 76/100
250/250 - 47s - loss: 0.0075 - bit_err: 0.0101 - val_loss: 0.0070 - val_bit_err:
0.0096
Epoch 77/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0101 - val_loss: 0.0076 - val_bit_err:
0.0104
Epoch 78/100
250/250 - 47s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0092 - val_bit_err:
0.0121
Epoch 79/100
250/250 - 47s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0076 - val_bit_err:
0.0101
Epoch 80/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0071 - val_bit_err:
0.0100
Epoch 81/100
250/250 - 47s - loss: 0.0073 - bit_err: 0.0098 - val_loss: 0.0074 - val_bit_err:
0.0100
Epoch 82/100
250/250 - 48s - loss: 0.0073 - bit_err: 0.0098 - val_loss: 0.0075 - val_bit_err:
0.0104
Epoch 83/100
250/250 - 48s - loss: 0.0073 - bit_err: 0.0098 - val_loss: 0.0086 - val_bit_err:
0.0122
Epoch 84/100
250/250 - 48s - loss: 0.0072 - bit_err: 0.0097 - val_loss: 0.0076 - val_bit_err:
0.0096
Epoch 85/100
250/250 - 48s - loss: 0.0072 - bit_err: 0.0098 - val_loss: 0.0080 - val_bit_err:
0.0107
Epoch 86/100
250/250 - 48s - loss: 0.0072 - bit_err: 0.0097 - val_loss: 0.0081 - val_bit_err:
0.0113
Epoch 87/100
250/250 - 47s - loss: 0.0072 - bit_err: 0.0097 - val_loss: 0.0070 - val_bit_err:

```

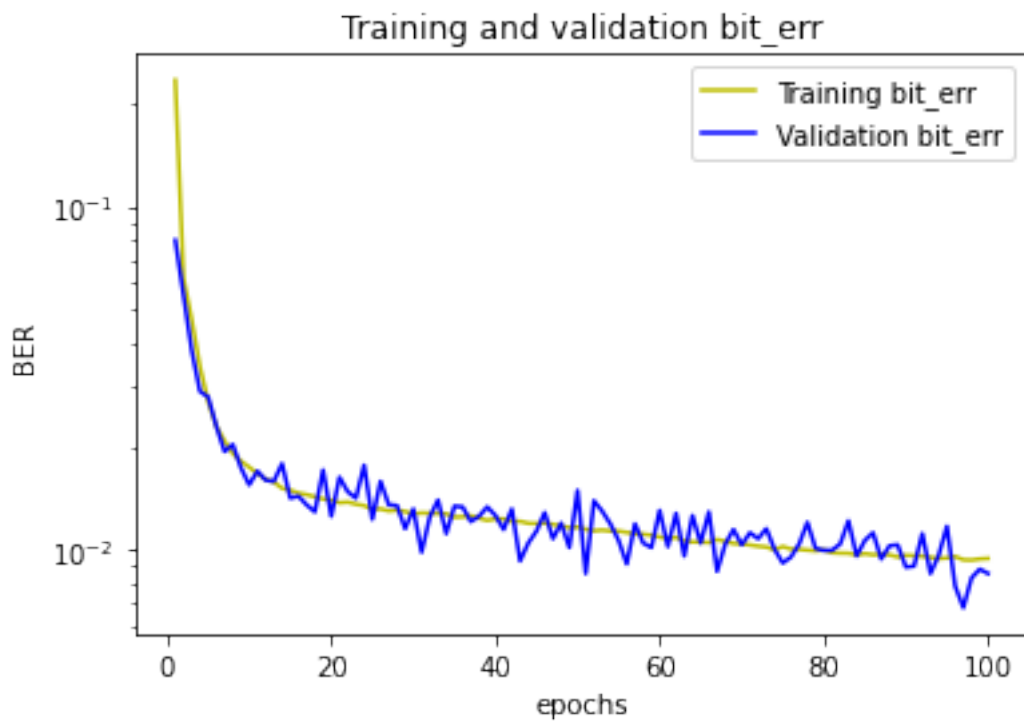
0.0094
Epoch 88/100
250/250 - 47s - loss: 0.0072 - bit_err: 0.0097 - val_loss: 0.0070 - val_bit_err:
0.0103
Epoch 89/100
250/250 - 47s - loss: 0.0071 - bit_err: 0.0096 - val_loss: 0.0078 - val_bit_err:
0.0104
Epoch 90/100
250/250 - 48s - loss: 0.0072 - bit_err: 0.0097 - val_loss: 0.0067 - val_bit_err:
0.0089
Epoch 91/100
250/250 - 48s - loss: 0.0071 - bit_err: 0.0096 - val_loss: 0.0069 - val_bit_err:
0.0090
Epoch 92/100
250/250 - 47s - loss: 0.0071 - bit_err: 0.0096 - val_loss: 0.0082 - val_bit_err:
0.0112
Epoch 93/100
250/250 - 47s - loss: 0.0071 - bit_err: 0.0095 - val_loss: 0.0062 - val_bit_err:
0.0086
Epoch 94/100
250/250 - 48s - loss: 0.0070 - bit_err: 0.0095 - val_loss: 0.0068 - val_bit_err:
0.0097
Epoch 95/100
250/250 - 47s - loss: 0.0070 - bit_err: 0.0095 - val_loss: 0.0083 - val_bit_err:
0.0117
Epoch 96/100
250/250 - 48s - loss: 0.0071 - bit_err: 0.0096 - val_loss: 0.0061 - val_bit_err:
0.0079
Epoch 97/100
250/250 - 47s - loss: 0.0070 - bit_err: 0.0094 - val_loss: 0.0050 - val_bit_err:
0.0068
Epoch 98/100
250/250 - 48s - loss: 0.0069 - bit_err: 0.0094 - val_loss: 0.0066 - val_bit_err:
0.0083
Epoch 99/100
250/250 - 47s - loss: 0.0070 - bit_err: 0.0094 - val_loss: 0.0065 - val_bit_err:
0.0088
Epoch 100/100
250/250 - 47s - loss: 0.0070 - bit_err: 0.0095 - val_loss: 0.0062 - val_bit_err:
0.0086
1/1 [=====] - 0s 2ms/step - loss: 0.1264 - bit_err:
0.1406
1/1 [=====] - 0s 2ms/step - loss: 0.0879 - bit_err:
0.0998
1/1 [=====] - 0s 2ms/step - loss: 0.0562 - bit_err:
0.0654
1/1 [=====] - 0s 2ms/step - loss: 0.0360 - bit_err:
0.0434

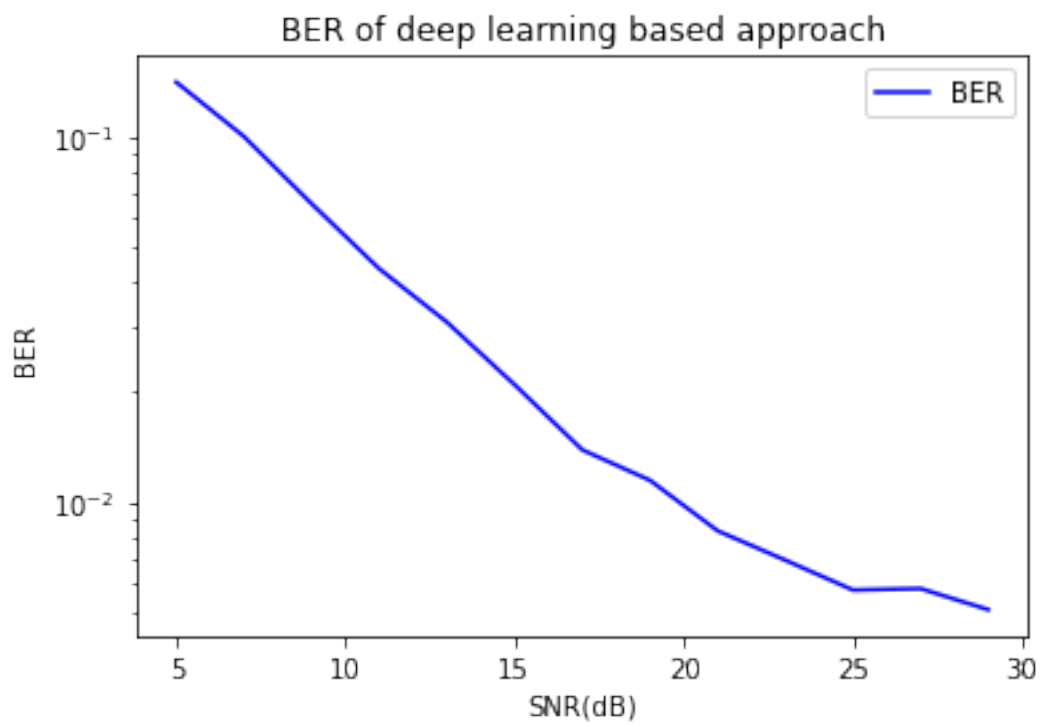
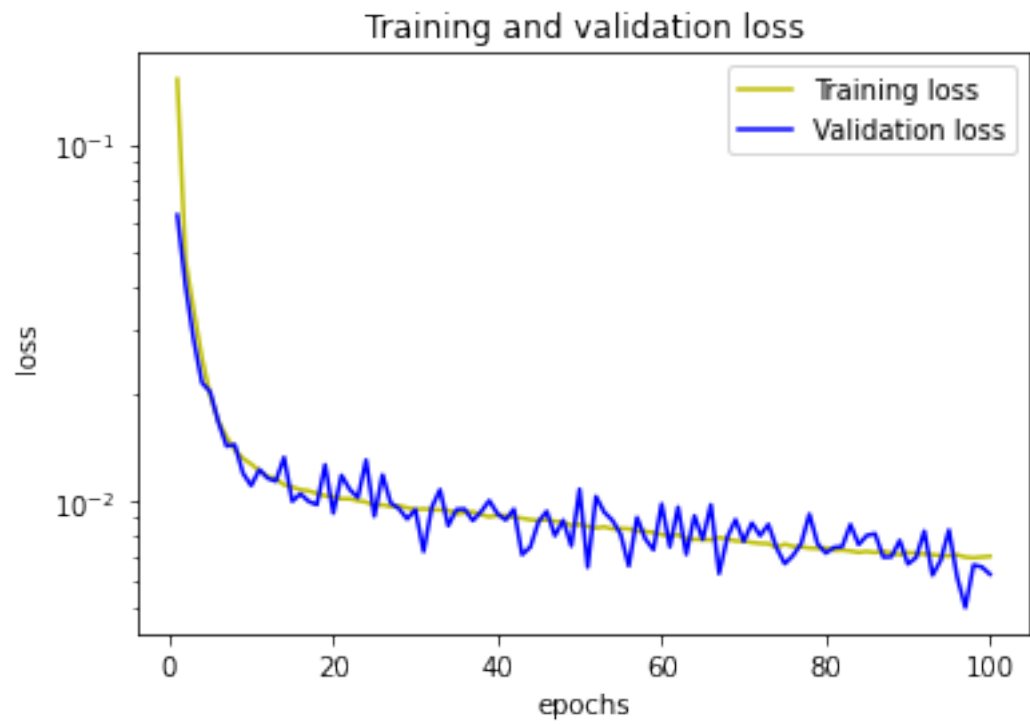
```

```

1/1 [=====] - 0s 1ms/step - loss: 0.0249 - bit_err:
0.0310
1/1 [=====] - 0s 2ms/step - loss: 0.0163 - bit_err:
0.0209
1/1 [=====] - 0s 2ms/step - loss: 0.0106 - bit_err:
0.0139
1/1 [=====] - 0s 2ms/step - loss: 0.0085 - bit_err:
0.0115
1/1 [=====] - 0s 2ms/step - loss: 0.0061 - bit_err:
0.0083
1/1 [=====] - 0s 2ms/step - loss: 0.0050 - bit_err:
0.0069
1/1 [=====] - 0s 6ms/step - loss: 0.0043 - bit_err:
0.0057
1/1 [=====] - 0s 2ms/step - loss: 0.0044 - bit_err:
0.0058
1/1 [=====] - 0s 3ms/step - loss: 0.0039 - bit_err:
0.0051

```





CP = 0, P = 64, activation = relu, lr = 0.001

```
[13]: run_all(0, 64, "relu", 0.001)
```

Epoch 1/100

250/250 - 51s - loss: 0.1197 - bit_err: 0.1668 - val_loss: 0.0450 - val_bit_err: 0.0526

Epoch 2/100

250/250 - 51s - loss: 0.0351 - bit_err: 0.0439 - val_loss: 0.0232 - val_bit_err: 0.0295

Epoch 3/100

250/250 - 51s - loss: 0.0223 - bit_err: 0.0288 - val_loss: 0.0224 - val_bit_err: 0.0301

Epoch 4/100

250/250 - 51s - loss: 0.0169 - bit_err: 0.0222 - val_loss: 0.0303 - val_bit_err: 0.0383

Epoch 5/100

250/250 - 51s - loss: 0.0140 - bit_err: 0.0188 - val_loss: 0.0131 - val_bit_err: 0.0182

Epoch 6/100

250/250 - 51s - loss: 0.0122 - bit_err: 0.0165 - val_loss: 0.0130 - val_bit_err: 0.0181

Epoch 7/100

250/250 - 51s - loss: 0.0112 - bit_err: 0.0152 - val_loss: 0.0098 - val_bit_err: 0.0138

Epoch 8/100

250/250 - 51s - loss: 0.0103 - bit_err: 0.0140 - val_loss: 0.0089 - val_bit_err: 0.0120

Epoch 9/100

250/250 - 51s - loss: 0.0095 - bit_err: 0.0129 - val_loss: 0.0110 - val_bit_err: 0.0156

Epoch 10/100

250/250 - 51s - loss: 0.0091 - bit_err: 0.0124 - val_loss: 0.0095 - val_bit_err: 0.0126

Epoch 11/100

250/250 - 51s - loss: 0.0087 - bit_err: 0.0118 - val_loss: 0.0106 - val_bit_err: 0.0148

Epoch 12/100

250/250 - 51s - loss: 0.0084 - bit_err: 0.0114 - val_loss: 0.0078 - val_bit_err: 0.0105

Epoch 13/100

250/250 - 51s - loss: 0.0081 - bit_err: 0.0109 - val_loss: 0.0086 - val_bit_err: 0.0111

Epoch 14/100

250/250 - 51s - loss: 0.0080 - bit_err: 0.0108 - val_loss: 0.0072 - val_bit_err: 0.0098

Epoch 15/100

250/250 - 51s - loss: 0.0078 - bit_err: 0.0104 - val_loss: 0.0067 - val_bit_err:

0.0089
Epoch 16/100
250/250 - 51s - loss: 0.0076 - bit_err: 0.0102 - val_loss: 0.0077 - val_bit_err: 0.0102
Epoch 17/100
250/250 - 51s - loss: 0.0075 - bit_err: 0.0101 - val_loss: 0.0087 - val_bit_err: 0.0120
Epoch 18/100
250/250 - 51s - loss: 0.0074 - bit_err: 0.0099 - val_loss: 0.0075 - val_bit_err: 0.0094
Epoch 19/100
250/250 - 51s - loss: 0.0075 - bit_err: 0.0099 - val_loss: 0.0070 - val_bit_err: 0.0091
Epoch 20/100
250/250 - 51s - loss: 0.0073 - bit_err: 0.0097 - val_loss: 0.0069 - val_bit_err: 0.0094
Epoch 21/100
250/250 - 51s - loss: 0.0073 - bit_err: 0.0096 - val_loss: 0.0064 - val_bit_err: 0.0082
Epoch 22/100
250/250 - 51s - loss: 0.0072 - bit_err: 0.0095 - val_loss: 0.0081 - val_bit_err: 0.0108
Epoch 23/100
250/250 - 51s - loss: 0.0071 - bit_err: 0.0094 - val_loss: 0.0066 - val_bit_err: 0.0086
Epoch 24/100
250/250 - 50s - loss: 0.0071 - bit_err: 0.0093 - val_loss: 0.0068 - val_bit_err: 0.0089
Epoch 25/100
250/250 - 50s - loss: 0.0070 - bit_err: 0.0092 - val_loss: 0.0060 - val_bit_err: 0.0084
Epoch 26/100
250/250 - 50s - loss: 0.0070 - bit_err: 0.0092 - val_loss: 0.0071 - val_bit_err: 0.0094
Epoch 27/100
250/250 - 51s - loss: 0.0069 - bit_err: 0.0091 - val_loss: 0.0071 - val_bit_err: 0.0089
Epoch 28/100
250/250 - 51s - loss: 0.0070 - bit_err: 0.0091 - val_loss: 0.0071 - val_bit_err: 0.0092
Epoch 29/100
250/250 - 50s - loss: 0.0069 - bit_err: 0.0090 - val_loss: 0.0074 - val_bit_err: 0.0098
Epoch 30/100
250/250 - 50s - loss: 0.0068 - bit_err: 0.0089 - val_loss: 0.0082 - val_bit_err: 0.0111
Epoch 31/100
250/250 - 51s - loss: 0.0068 - bit_err: 0.0089 - val_loss: 0.0079 - val_bit_err:

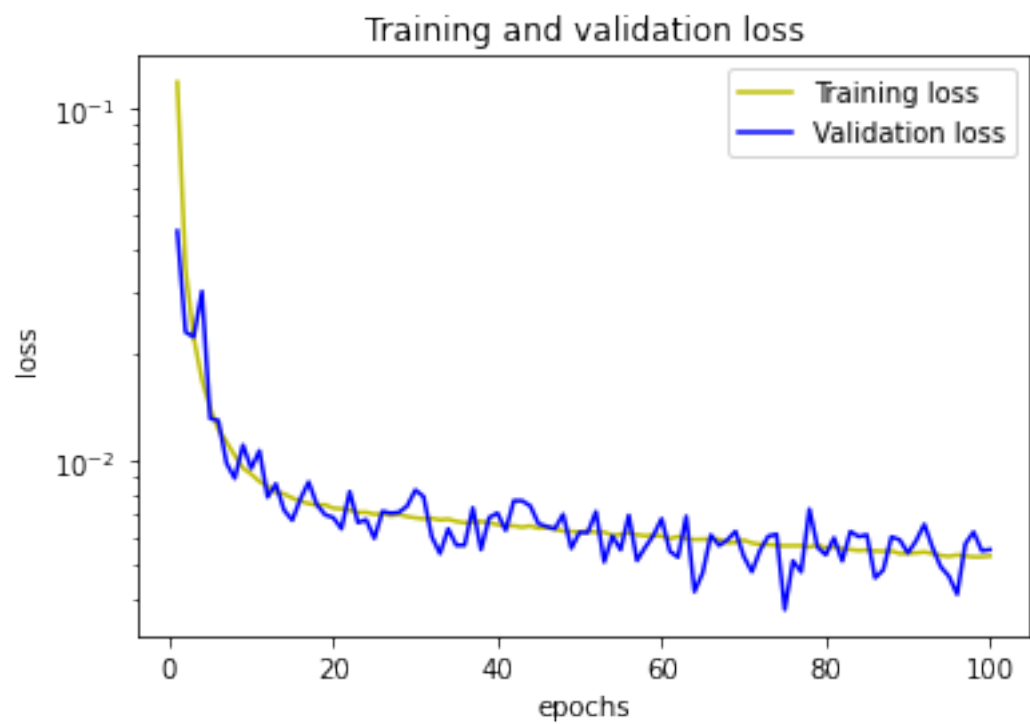
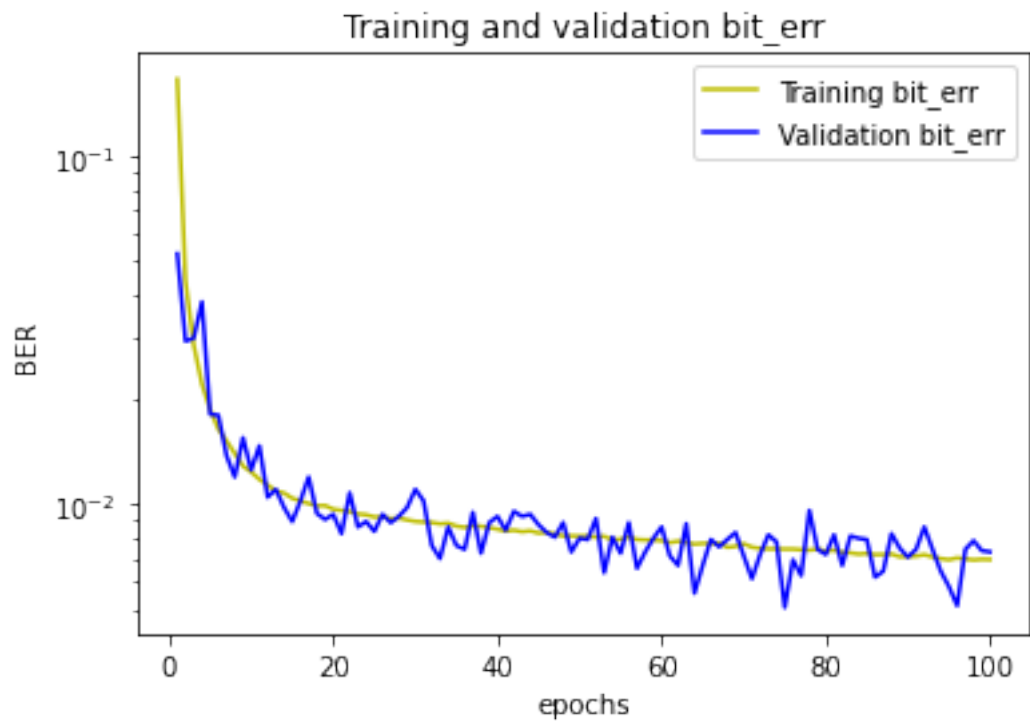
0.0102
Epoch 32/100
250/250 - 50s - loss: 0.0068 - bit_err: 0.0089 - val_loss: 0.0060 - val_bit_err:
0.0076
Epoch 33/100
250/250 - 50s - loss: 0.0068 - bit_err: 0.0088 - val_loss: 0.0054 - val_bit_err:
0.0070
Epoch 34/100
250/250 - 50s - loss: 0.0068 - bit_err: 0.0088 - val_loss: 0.0064 - val_bit_err:
0.0086
Epoch 35/100
250/250 - 51s - loss: 0.0067 - bit_err: 0.0087 - val_loss: 0.0057 - val_bit_err:
0.0076
Epoch 36/100
250/250 - 50s - loss: 0.0066 - bit_err: 0.0086 - val_loss: 0.0057 - val_bit_err:
0.0074
Epoch 37/100
250/250 - 51s - loss: 0.0066 - bit_err: 0.0087 - val_loss: 0.0073 - val_bit_err:
0.0095
Epoch 38/100
250/250 - 51s - loss: 0.0067 - bit_err: 0.0087 - val_loss: 0.0056 - val_bit_err:
0.0073
Epoch 39/100
250/250 - 51s - loss: 0.0066 - bit_err: 0.0086 - val_loss: 0.0069 - val_bit_err:
0.0089
Epoch 40/100
250/250 - 50s - loss: 0.0065 - bit_err: 0.0085 - val_loss: 0.0071 - val_bit_err:
0.0092
Epoch 41/100
250/250 - 51s - loss: 0.0065 - bit_err: 0.0084 - val_loss: 0.0063 - val_bit_err:
0.0084
Epoch 42/100
250/250 - 51s - loss: 0.0065 - bit_err: 0.0084 - val_loss: 0.0077 - val_bit_err:
0.0096
Epoch 43/100
250/250 - 51s - loss: 0.0064 - bit_err: 0.0084 - val_loss: 0.0077 - val_bit_err:
0.0092
Epoch 44/100
250/250 - 50s - loss: 0.0065 - bit_err: 0.0084 - val_loss: 0.0074 - val_bit_err:
0.0094
Epoch 45/100
250/250 - 50s - loss: 0.0064 - bit_err: 0.0083 - val_loss: 0.0066 - val_bit_err:
0.0088
Epoch 46/100
250/250 - 51s - loss: 0.0064 - bit_err: 0.0083 - val_loss: 0.0065 - val_bit_err:
0.0083
Epoch 47/100
250/250 - 50s - loss: 0.0063 - bit_err: 0.0082 - val_loss: 0.0064 - val_bit_err:

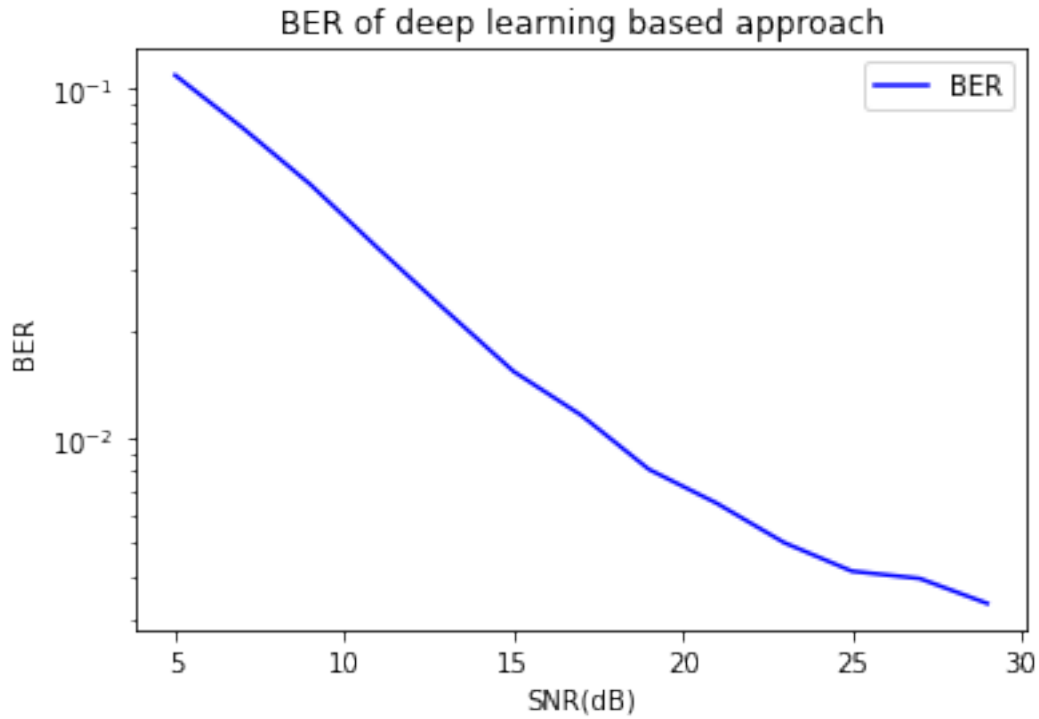
0.0081
 Epoch 48/100
 250/250 - 50s - loss: 0.0063 - bit_err: 0.0081 - val_loss: 0.0070 - val_bit_err:
 0.0089
 Epoch 49/100
 250/250 - 50s - loss: 0.0063 - bit_err: 0.0081 - val_loss: 0.0056 - val_bit_err:
 0.0073
 Epoch 50/100
 250/250 - 50s - loss: 0.0062 - bit_err: 0.0081 - val_loss: 0.0062 - val_bit_err:
 0.0080
 Epoch 51/100
 250/250 - 50s - loss: 0.0063 - bit_err: 0.0081 - val_loss: 0.0062 - val_bit_err:
 0.0079
 Epoch 52/100
 250/250 - 50s - loss: 0.0062 - bit_err: 0.0081 - val_loss: 0.0071 - val_bit_err:
 0.0091
 Epoch 53/100
 250/250 - 50s - loss: 0.0062 - bit_err: 0.0081 - val_loss: 0.0051 - val_bit_err:
 0.0064
 Epoch 54/100
 250/250 - 50s - loss: 0.0061 - bit_err: 0.0079 - val_loss: 0.0061 - val_bit_err:
 0.0081
 Epoch 55/100
 250/250 - 50s - loss: 0.0061 - bit_err: 0.0080 - val_loss: 0.0055 - val_bit_err:
 0.0073
 Epoch 56/100
 250/250 - 50s - loss: 0.0062 - bit_err: 0.0081 - val_loss: 0.0070 - val_bit_err:
 0.0089
 Epoch 57/100
 250/250 - 50s - loss: 0.0061 - bit_err: 0.0079 - val_loss: 0.0052 - val_bit_err:
 0.0066
 Epoch 58/100
 250/250 - 51s - loss: 0.0061 - bit_err: 0.0079 - val_loss: 0.0056 - val_bit_err:
 0.0073
 Epoch 59/100
 250/250 - 50s - loss: 0.0061 - bit_err: 0.0079 - val_loss: 0.0061 - val_bit_err:
 0.0080
 Epoch 60/100
 250/250 - 50s - loss: 0.0061 - bit_err: 0.0079 - val_loss: 0.0068 - val_bit_err:
 0.0086
 Epoch 61/100
 250/250 - 51s - loss: 0.0060 - bit_err: 0.0078 - val_loss: 0.0055 - val_bit_err:
 0.0071
 Epoch 62/100
 250/250 - 51s - loss: 0.0060 - bit_err: 0.0079 - val_loss: 0.0053 - val_bit_err:
 0.0067
 Epoch 63/100
 250/250 - 50s - loss: 0.0060 - bit_err: 0.0078 - val_loss: 0.0069 - val_bit_err:

0.0088
Epoch 64/100
250/250 - 50s - loss: 0.0059 - bit_err: 0.0077 - val_loss: 0.0042 - val_bit_err: 0.0056
Epoch 65/100
250/250 - 50s - loss: 0.0059 - bit_err: 0.0077 - val_loss: 0.0048 - val_bit_err: 0.0067
Epoch 66/100
250/250 - 50s - loss: 0.0059 - bit_err: 0.0077 - val_loss: 0.0061 - val_bit_err: 0.0079
Epoch 67/100
250/250 - 50s - loss: 0.0060 - bit_err: 0.0078 - val_loss: 0.0057 - val_bit_err: 0.0076
Epoch 68/100
250/250 - 50s - loss: 0.0058 - bit_err: 0.0075 - val_loss: 0.0059 - val_bit_err: 0.0079
Epoch 69/100
250/250 - 50s - loss: 0.0058 - bit_err: 0.0076 - val_loss: 0.0063 - val_bit_err: 0.0083
Epoch 70/100
250/250 - 50s - loss: 0.0059 - bit_err: 0.0077 - val_loss: 0.0053 - val_bit_err: 0.0071
Epoch 71/100
250/250 - 50s - loss: 0.0058 - bit_err: 0.0075 - val_loss: 0.0048 - val_bit_err: 0.0061
Epoch 72/100
250/250 - 50s - loss: 0.0057 - bit_err: 0.0075 - val_loss: 0.0055 - val_bit_err: 0.0072
Epoch 73/100
250/250 - 50s - loss: 0.0057 - bit_err: 0.0075 - val_loss: 0.0061 - val_bit_err: 0.0082
Epoch 74/100
250/250 - 50s - loss: 0.0057 - bit_err: 0.0075 - val_loss: 0.0061 - val_bit_err: 0.0078
Epoch 75/100
250/250 - 50s - loss: 0.0057 - bit_err: 0.0075 - val_loss: 0.0037 - val_bit_err: 0.0051
Epoch 76/100
250/250 - 51s - loss: 0.0057 - bit_err: 0.0074 - val_loss: 0.0052 - val_bit_err: 0.0069
Epoch 77/100
250/250 - 51s - loss: 0.0057 - bit_err: 0.0074 - val_loss: 0.0048 - val_bit_err: 0.0063
Epoch 78/100
250/250 - 52s - loss: 0.0057 - bit_err: 0.0074 - val_loss: 0.0072 - val_bit_err: 0.0096
Epoch 79/100
250/250 - 51s - loss: 0.0057 - bit_err: 0.0075 - val_loss: 0.0056 - val_bit_err:

0.0074
Epoch 80/100
250/250 - 50s - loss: 0.0056 - bit_err: 0.0074 - val_loss: 0.0054 - val_bit_err: 0.0072
Epoch 81/100
250/250 - 50s - loss: 0.0057 - bit_err: 0.0074 - val_loss: 0.0060 - val_bit_err: 0.0082
Epoch 82/100
250/250 - 50s - loss: 0.0056 - bit_err: 0.0073 - val_loss: 0.0052 - val_bit_err: 0.0067
Epoch 83/100
250/250 - 51s - loss: 0.0056 - bit_err: 0.0073 - val_loss: 0.0063 - val_bit_err: 0.0081
Epoch 84/100
250/250 - 51s - loss: 0.0055 - bit_err: 0.0072 - val_loss: 0.0060 - val_bit_err: 0.0080
Epoch 85/100
250/250 - 50s - loss: 0.0055 - bit_err: 0.0072 - val_loss: 0.0061 - val_bit_err: 0.0079
Epoch 86/100
250/250 - 50s - loss: 0.0055 - bit_err: 0.0072 - val_loss: 0.0046 - val_bit_err: 0.0062
Epoch 87/100
250/250 - 50s - loss: 0.0055 - bit_err: 0.0072 - val_loss: 0.0049 - val_bit_err: 0.0064
Epoch 88/100
250/250 - 51s - loss: 0.0055 - bit_err: 0.0072 - val_loss: 0.0060 - val_bit_err: 0.0082
Epoch 89/100
250/250 - 50s - loss: 0.0054 - bit_err: 0.0071 - val_loss: 0.0059 - val_bit_err: 0.0075
Epoch 90/100
250/250 - 50s - loss: 0.0054 - bit_err: 0.0071 - val_loss: 0.0054 - val_bit_err: 0.0071
Epoch 91/100
250/250 - 51s - loss: 0.0054 - bit_err: 0.0071 - val_loss: 0.0059 - val_bit_err: 0.0074
Epoch 92/100
250/250 - 51s - loss: 0.0055 - bit_err: 0.0072 - val_loss: 0.0066 - val_bit_err: 0.0086
Epoch 93/100
250/250 - 51s - loss: 0.0054 - bit_err: 0.0071 - val_loss: 0.0056 - val_bit_err: 0.0074
Epoch 94/100
250/250 - 50s - loss: 0.0053 - bit_err: 0.0070 - val_loss: 0.0050 - val_bit_err: 0.0064
Epoch 95/100
250/250 - 50s - loss: 0.0053 - bit_err: 0.0069 - val_loss: 0.0047 - val_bit_err:

0.0058
 Epoch 96/100
 250/250 - 50s - loss: 0.0054 - bit_err: 0.0070 - val_loss: 0.0041 - val_bit_err:
 0.0051
 Epoch 97/100
 250/250 - 50s - loss: 0.0053 - bit_err: 0.0070 - val_loss: 0.0058 - val_bit_err:
 0.0074
 Epoch 98/100
 250/250 - 51s - loss: 0.0053 - bit_err: 0.0069 - val_loss: 0.0062 - val_bit_err:
 0.0079
 Epoch 99/100
 250/250 - 51s - loss: 0.0053 - bit_err: 0.0070 - val_loss: 0.0055 - val_bit_err:
 0.0074
 Epoch 100/100
 250/250 - 50s - loss: 0.0053 - bit_err: 0.0070 - val_loss: 0.0056 - val_bit_err:
 0.0073
 1/1 [=====] - 0s 2ms/step - loss: 0.0988 - bit_err:
 0.1089
 1/1 [=====] - 0s 2ms/step - loss: 0.0681 - bit_err:
 0.0768
 1/1 [=====] - 0s 2ms/step - loss: 0.0460 - bit_err:
 0.0529
 1/1 [=====] - 0s 2ms/step - loss: 0.0294 - bit_err:
 0.0348
 1/1 [=====] - 0s 2ms/step - loss: 0.0192 - bit_err:
 0.0231
 1/1 [=====] - 0s 2ms/step - loss: 0.0125 - bit_err:
 0.0155
 1/1 [=====] - 0s 2ms/step - loss: 0.0090 - bit_err:
 0.0116
 1/1 [=====] - 0s 2ms/step - loss: 0.0062 - bit_err:
 0.0081
 1/1 [=====] - 0s 2ms/step - loss: 0.0049 - bit_err:
 0.0065
 1/1 [=====] - 0s 2ms/step - loss: 0.0039 - bit_err:
 0.0050
 1/1 [=====] - 0s 2ms/step - loss: 0.0032 - bit_err:
 0.0041
 1/1 [=====] - 0s 2ms/step - loss: 0.0029 - bit_err:
 0.0039
 1/1 [=====] - 0s 2ms/step - loss: 0.0025 - bit_err:
 0.0034





CP = 0, P = 8, activation = relu, lr = 0.001

```
[14]: run_all(0, 8, "relu", 0.001)
```

Epoch 1/100

250/250 - 51s - loss: 0.1547 - bit_err: 0.2381 - val_loss: 0.0667 - val_bit_err: 0.0832

Epoch 2/100

250/250 - 50s - loss: 0.0513 - bit_err: 0.0673 - val_loss: 0.0409 - val_bit_err: 0.0583

Epoch 3/100

250/250 - 51s - loss: 0.0388 - bit_err: 0.0529 - val_loss: 0.0335 - val_bit_err: 0.0469

Epoch 4/100

250/250 - 51s - loss: 0.0297 - bit_err: 0.0405 - val_loss: 0.0259 - val_bit_err: 0.0346

Epoch 5/100

250/250 - 51s - loss: 0.0244 - bit_err: 0.0335 - val_loss: 0.0244 - val_bit_err: 0.0329

Epoch 6/100

250/250 - 50s - loss: 0.0215 - bit_err: 0.0295 - val_loss: 0.0187 - val_bit_err: 0.0257

Epoch 7/100

250/250 - 51s - loss: 0.0197 - bit_err: 0.0272 - val_loss: 0.0227 - val_bit_err:

0.0316
Epoch 8/100
250/250 - 50s - loss: 0.0187 - bit_err: 0.0257 - val_loss: 0.0161 - val_bit_err:
0.0213
Epoch 9/100
250/250 - 51s - loss: 0.0179 - bit_err: 0.0247 - val_loss: 0.0176 - val_bit_err:
0.0246
Epoch 10/100
250/250 - 50s - loss: 0.0173 - bit_err: 0.0237 - val_loss: 0.0164 - val_bit_err:
0.0217
Epoch 11/100
250/250 - 50s - loss: 0.0169 - bit_err: 0.0231 - val_loss: 0.0179 - val_bit_err:
0.0250
Epoch 12/100
250/250 - 50s - loss: 0.0163 - bit_err: 0.0223 - val_loss: 0.0169 - val_bit_err:
0.0238
Epoch 13/100
250/250 - 51s - loss: 0.0162 - bit_err: 0.0221 - val_loss: 0.0147 - val_bit_err:
0.0196
Epoch 14/100
250/250 - 50s - loss: 0.0158 - bit_err: 0.0216 - val_loss: 0.0156 - val_bit_err:
0.0221
Epoch 15/100
250/250 - 51s - loss: 0.0157 - bit_err: 0.0215 - val_loss: 0.0168 - val_bit_err:
0.0226
Epoch 16/100
250/250 - 51s - loss: 0.0153 - bit_err: 0.0209 - val_loss: 0.0172 - val_bit_err:
0.0241
Epoch 17/100
250/250 - 50s - loss: 0.0153 - bit_err: 0.0208 - val_loss: 0.0132 - val_bit_err:
0.0174
Epoch 18/100
250/250 - 51s - loss: 0.0152 - bit_err: 0.0206 - val_loss: 0.0146 - val_bit_err:
0.0191
Epoch 19/100
250/250 - 50s - loss: 0.0149 - bit_err: 0.0203 - val_loss: 0.0152 - val_bit_err:
0.0206
Epoch 20/100
250/250 - 51s - loss: 0.0148 - bit_err: 0.0201 - val_loss: 0.0132 - val_bit_err:
0.0186
Epoch 21/100
250/250 - 50s - loss: 0.0147 - bit_err: 0.0199 - val_loss: 0.0155 - val_bit_err:
0.0216
Epoch 22/100
250/250 - 50s - loss: 0.0145 - bit_err: 0.0197 - val_loss: 0.0132 - val_bit_err:
0.0179
Epoch 23/100
250/250 - 50s - loss: 0.0144 - bit_err: 0.0194 - val_loss: 0.0154 - val_bit_err:

0.0212
Epoch 24/100
250/250 - 51s - loss: 0.0147 - bit_err: 0.0199 - val_loss: 0.0154 - val_bit_err:
0.0208
Epoch 25/100
250/250 - 51s - loss: 0.0144 - bit_err: 0.0196 - val_loss: 0.0148 - val_bit_err:
0.0203
Epoch 26/100
250/250 - 50s - loss: 0.0142 - bit_err: 0.0192 - val_loss: 0.0133 - val_bit_err:
0.0174
Epoch 27/100
250/250 - 50s - loss: 0.0141 - bit_err: 0.0191 - val_loss: 0.0131 - val_bit_err:
0.0188
Epoch 28/100
250/250 - 51s - loss: 0.0141 - bit_err: 0.0191 - val_loss: 0.0161 - val_bit_err:
0.0222
Epoch 29/100
250/250 - 50s - loss: 0.0140 - bit_err: 0.0189 - val_loss: 0.0151 - val_bit_err:
0.0206
Epoch 30/100
250/250 - 51s - loss: 0.0138 - bit_err: 0.0188 - val_loss: 0.0144 - val_bit_err:
0.0199
Epoch 31/100
250/250 - 50s - loss: 0.0138 - bit_err: 0.0187 - val_loss: 0.0144 - val_bit_err:
0.0195
Epoch 32/100
250/250 - 51s - loss: 0.0138 - bit_err: 0.0188 - val_loss: 0.0121 - val_bit_err:
0.0161
Epoch 33/100
250/250 - 51s - loss: 0.0137 - bit_err: 0.0185 - val_loss: 0.0125 - val_bit_err:
0.0176
Epoch 34/100
250/250 - 51s - loss: 0.0135 - bit_err: 0.0182 - val_loss: 0.0147 - val_bit_err:
0.0205
Epoch 35/100
250/250 - 51s - loss: 0.0135 - bit_err: 0.0182 - val_loss: 0.0132 - val_bit_err:
0.0181
Epoch 36/100
250/250 - 50s - loss: 0.0135 - bit_err: 0.0182 - val_loss: 0.0159 - val_bit_err:
0.0212
Epoch 37/100
250/250 - 51s - loss: 0.0133 - bit_err: 0.0180 - val_loss: 0.0161 - val_bit_err:
0.0213
Epoch 38/100
250/250 - 51s - loss: 0.0134 - bit_err: 0.0181 - val_loss: 0.0132 - val_bit_err:
0.0176
Epoch 39/100
250/250 - 50s - loss: 0.0133 - bit_err: 0.0180 - val_loss: 0.0116 - val_bit_err:

0.0156
Epoch 40/100
250/250 - 50s - loss: 0.0132 - bit_err: 0.0179 - val_loss: 0.0128 - val_bit_err: 0.0169
Epoch 41/100
250/250 - 50s - loss: 0.0133 - bit_err: 0.0180 - val_loss: 0.0153 - val_bit_err: 0.0219
Epoch 42/100
250/250 - 50s - loss: 0.0132 - bit_err: 0.0179 - val_loss: 0.0144 - val_bit_err: 0.0198
Epoch 43/100
250/250 - 50s - loss: 0.0131 - bit_err: 0.0177 - val_loss: 0.0136 - val_bit_err: 0.0183
Epoch 44/100
250/250 - 50s - loss: 0.0131 - bit_err: 0.0178 - val_loss: 0.0144 - val_bit_err: 0.0190
Epoch 45/100
250/250 - 50s - loss: 0.0131 - bit_err: 0.0178 - val_loss: 0.0163 - val_bit_err: 0.0220
Epoch 46/100
250/250 - 51s - loss: 0.0130 - bit_err: 0.0176 - val_loss: 0.0146 - val_bit_err: 0.0198
Epoch 47/100
250/250 - 51s - loss: 0.0128 - bit_err: 0.0174 - val_loss: 0.0119 - val_bit_err: 0.0157
Epoch 48/100
250/250 - 51s - loss: 0.0128 - bit_err: 0.0174 - val_loss: 0.0134 - val_bit_err: 0.0187
Epoch 49/100
250/250 - 51s - loss: 0.0127 - bit_err: 0.0173 - val_loss: 0.0140 - val_bit_err: 0.0190
Epoch 50/100
250/250 - 50s - loss: 0.0127 - bit_err: 0.0171 - val_loss: 0.0143 - val_bit_err: 0.0191
Epoch 51/100
250/250 - 50s - loss: 0.0128 - bit_err: 0.0173 - val_loss: 0.0126 - val_bit_err: 0.0168
Epoch 52/100
250/250 - 51s - loss: 0.0126 - bit_err: 0.0170 - val_loss: 0.0111 - val_bit_err: 0.0154
Epoch 53/100
250/250 - 50s - loss: 0.0126 - bit_err: 0.0171 - val_loss: 0.0132 - val_bit_err: 0.0178
Epoch 54/100
250/250 - 50s - loss: 0.0125 - bit_err: 0.0169 - val_loss: 0.0117 - val_bit_err: 0.0163
Epoch 55/100
250/250 - 51s - loss: 0.0126 - bit_err: 0.0171 - val_loss: 0.0125 - val_bit_err:

0.0167
Epoch 56/100
250/250 - 50s - loss: 0.0125 - bit_err: 0.0169 - val_loss: 0.0111 - val_bit_err:
0.0148
Epoch 57/100
250/250 - 51s - loss: 0.0124 - bit_err: 0.0167 - val_loss: 0.0132 - val_bit_err:
0.0180
Epoch 58/100
250/250 - 50s - loss: 0.0123 - bit_err: 0.0167 - val_loss: 0.0123 - val_bit_err:
0.0169
Epoch 59/100
250/250 - 52s - loss: 0.0122 - bit_err: 0.0165 - val_loss: 0.0125 - val_bit_err:
0.0169
Epoch 60/100
250/250 - 50s - loss: 0.0122 - bit_err: 0.0166 - val_loss: 0.0106 - val_bit_err:
0.0144
Epoch 61/100
250/250 - 51s - loss: 0.0122 - bit_err: 0.0166 - val_loss: 0.0145 - val_bit_err:
0.0199
Epoch 62/100
250/250 - 50s - loss: 0.0120 - bit_err: 0.0163 - val_loss: 0.0124 - val_bit_err:
0.0170
Epoch 63/100
250/250 - 50s - loss: 0.0120 - bit_err: 0.0163 - val_loss: 0.0114 - val_bit_err:
0.0160
Epoch 64/100
250/250 - 50s - loss: 0.0120 - bit_err: 0.0162 - val_loss: 0.0114 - val_bit_err:
0.0152
Epoch 65/100
250/250 - 51s - loss: 0.0120 - bit_err: 0.0162 - val_loss: 0.0120 - val_bit_err:
0.0160
Epoch 66/100
250/250 - 51s - loss: 0.0120 - bit_err: 0.0162 - val_loss: 0.0143 - val_bit_err:
0.0194
Epoch 67/100
250/250 - 51s - loss: 0.0120 - bit_err: 0.0163 - val_loss: 0.0119 - val_bit_err:
0.0160
Epoch 68/100
250/250 - 50s - loss: 0.0120 - bit_err: 0.0163 - val_loss: 0.0096 - val_bit_err:
0.0132
Epoch 69/100
250/250 - 50s - loss: 0.0118 - bit_err: 0.0160 - val_loss: 0.0123 - val_bit_err:
0.0171
Epoch 70/100
250/250 - 50s - loss: 0.0118 - bit_err: 0.0159 - val_loss: 0.0123 - val_bit_err:
0.0169
Epoch 71/100
250/250 - 51s - loss: 0.0116 - bit_err: 0.0157 - val_loss: 0.0104 - val_bit_err:

0.0147
Epoch 72/100
250/250 - 50s - loss: 0.0117 - bit_err: 0.0158 - val_loss: 0.0133 - val_bit_err:
0.0180
Epoch 73/100
250/250 - 51s - loss: 0.0117 - bit_err: 0.0158 - val_loss: 0.0118 - val_bit_err:
0.0161
Epoch 74/100
250/250 - 50s - loss: 0.0116 - bit_err: 0.0157 - val_loss: 0.0101 - val_bit_err:
0.0133
Epoch 75/100
250/250 - 51s - loss: 0.0115 - bit_err: 0.0157 - val_loss: 0.0102 - val_bit_err:
0.0146
Epoch 76/100
250/250 - 50s - loss: 0.0115 - bit_err: 0.0156 - val_loss: 0.0098 - val_bit_err:
0.0130
Epoch 77/100
250/250 - 50s - loss: 0.0114 - bit_err: 0.0155 - val_loss: 0.0104 - val_bit_err:
0.0138
Epoch 78/100
250/250 - 50s - loss: 0.0114 - bit_err: 0.0155 - val_loss: 0.0115 - val_bit_err:
0.0149
Epoch 79/100
250/250 - 50s - loss: 0.0114 - bit_err: 0.0154 - val_loss: 0.0111 - val_bit_err:
0.0148
Epoch 80/100
250/250 - 50s - loss: 0.0113 - bit_err: 0.0154 - val_loss: 0.0114 - val_bit_err:
0.0154
Epoch 81/100
250/250 - 50s - loss: 0.0113 - bit_err: 0.0153 - val_loss: 0.0127 - val_bit_err:
0.0171
Epoch 82/100
250/250 - 50s - loss: 0.0111 - bit_err: 0.0150 - val_loss: 0.0110 - val_bit_err:
0.0153
Epoch 83/100
250/250 - 50s - loss: 0.0111 - bit_err: 0.0150 - val_loss: 0.0131 - val_bit_err:
0.0179
Epoch 84/100
250/250 - 51s - loss: 0.0112 - bit_err: 0.0150 - val_loss: 0.0105 - val_bit_err:
0.0146
Epoch 85/100
250/250 - 50s - loss: 0.0111 - bit_err: 0.0151 - val_loss: 0.0114 - val_bit_err:
0.0154
Epoch 86/100
250/250 - 50s - loss: 0.0111 - bit_err: 0.0150 - val_loss: 0.0099 - val_bit_err:
0.0136
Epoch 87/100
250/250 - 51s - loss: 0.0111 - bit_err: 0.0150 - val_loss: 0.0121 - val_bit_err:

```

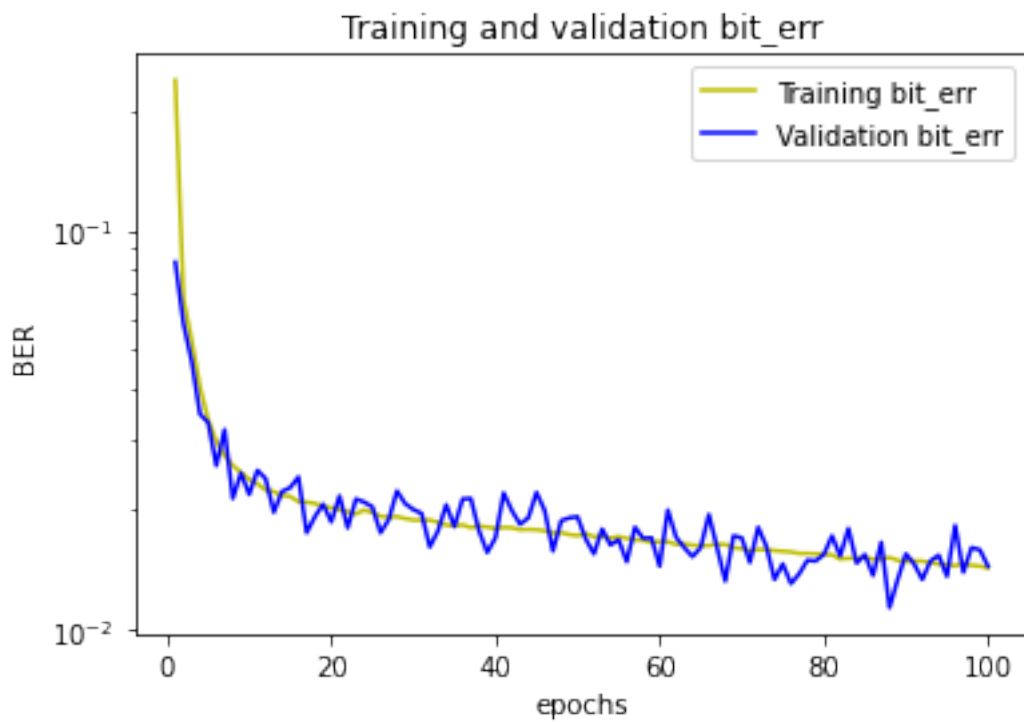
0.0165
Epoch 88/100
250/250 - 50s - loss: 0.0112 - bit_err: 0.0151 - val_loss: 0.0085 - val_bit_err:
0.0113
Epoch 89/100
250/250 - 51s - loss: 0.0110 - bit_err: 0.0149 - val_loss: 0.0096 - val_bit_err:
0.0133
Epoch 90/100
250/250 - 50s - loss: 0.0109 - bit_err: 0.0148 - val_loss: 0.0116 - val_bit_err:
0.0154
Epoch 91/100
250/250 - 50s - loss: 0.0110 - bit_err: 0.0148 - val_loss: 0.0104 - val_bit_err:
0.0146
Epoch 92/100
250/250 - 50s - loss: 0.0109 - bit_err: 0.0148 - val_loss: 0.0096 - val_bit_err:
0.0133
Epoch 93/100
250/250 - 50s - loss: 0.0108 - bit_err: 0.0147 - val_loss: 0.0110 - val_bit_err:
0.0148
Epoch 94/100
250/250 - 50s - loss: 0.0107 - bit_err: 0.0145 - val_loss: 0.0111 - val_bit_err:
0.0153
Epoch 95/100
250/250 - 51s - loss: 0.0107 - bit_err: 0.0145 - val_loss: 0.0095 - val_bit_err:
0.0136
Epoch 96/100
250/250 - 50s - loss: 0.0107 - bit_err: 0.0144 - val_loss: 0.0133 - val_bit_err:
0.0182
Epoch 97/100
250/250 - 50s - loss: 0.0108 - bit_err: 0.0146 - val_loss: 0.0102 - val_bit_err:
0.0139
Epoch 98/100
250/250 - 51s - loss: 0.0107 - bit_err: 0.0144 - val_loss: 0.0118 - val_bit_err:
0.0160
Epoch 99/100
250/250 - 50s - loss: 0.0107 - bit_err: 0.0144 - val_loss: 0.0121 - val_bit_err:
0.0158
Epoch 100/100
250/250 - 51s - loss: 0.0105 - bit_err: 0.0142 - val_loss: 0.0109 - val_bit_err:
0.0144
1/1 [=====] - 0s 2ms/step - loss: 0.1392 - bit_err:
0.1570
1/1 [=====] - 0s 2ms/step - loss: 0.0961 - bit_err:
0.1112
1/1 [=====] - 0s 4ms/step - loss: 0.0659 - bit_err:
0.0784
1/1 [=====] - 0s 2ms/step - loss: 0.0445 - bit_err:
0.0547

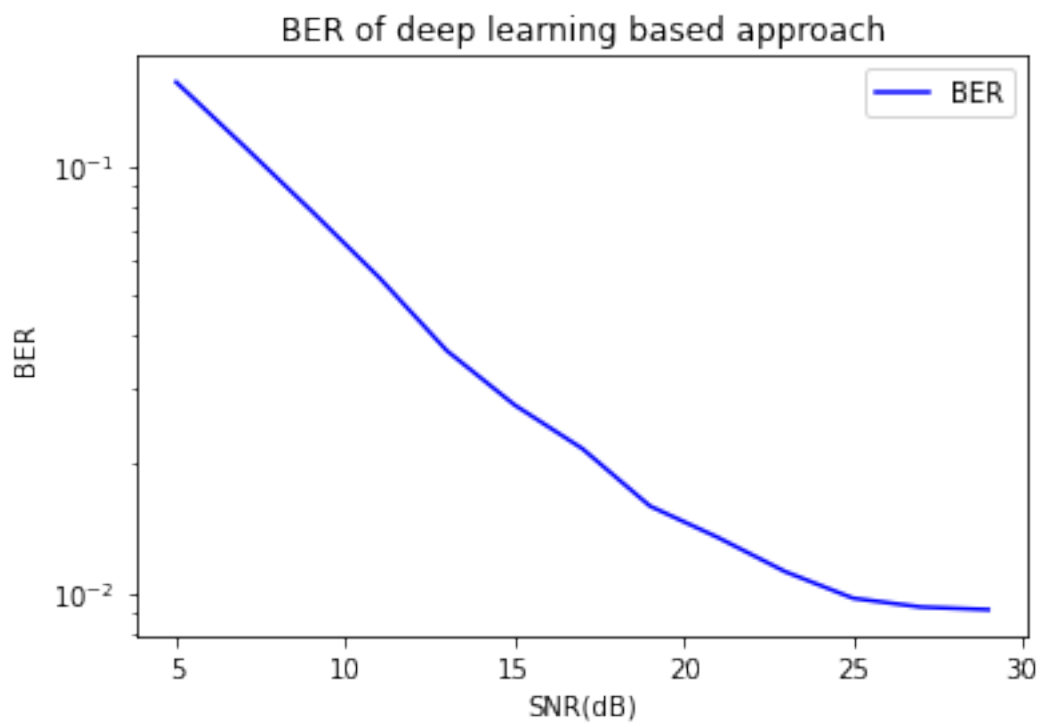
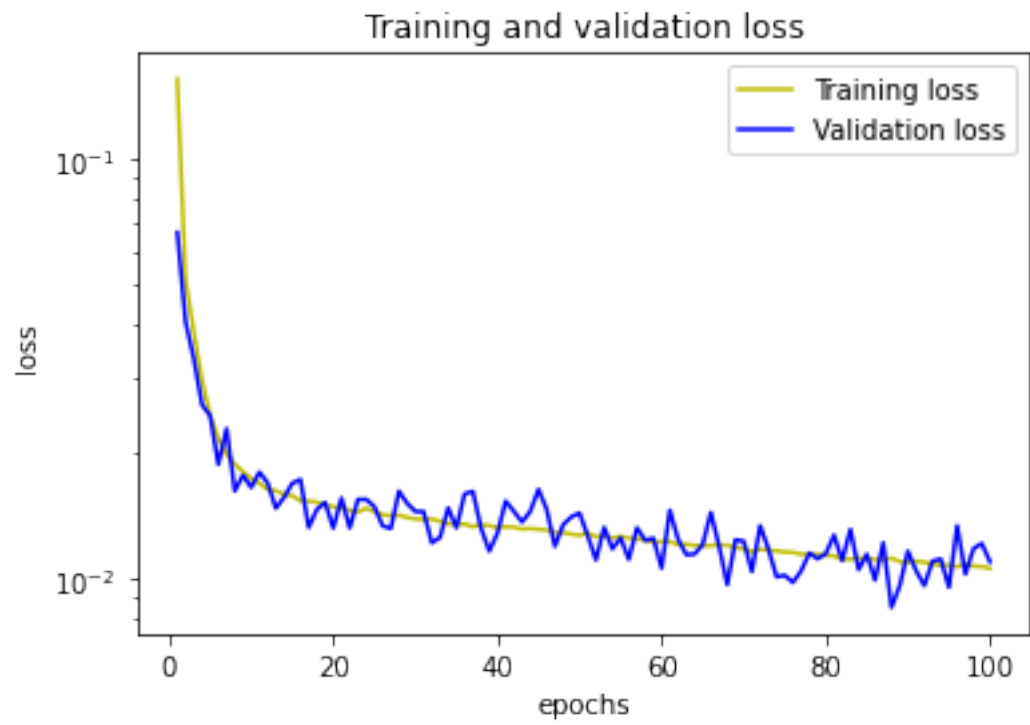
```

```

1/1 [=====] - 0s 2ms/step - loss: 0.0290 - bit_err:
0.0369
1/1 [=====] - 0s 2ms/step - loss: 0.0211 - bit_err:
0.0275
1/1 [=====] - 0s 1ms/step - loss: 0.0162 - bit_err:
0.0218
1/1 [=====] - 0s 2ms/step - loss: 0.0119 - bit_err:
0.0160
1/1 [=====] - 0s 2ms/step - loss: 0.0101 - bit_err:
0.0135
1/1 [=====] - 0s 1ms/step - loss: 0.0082 - bit_err:
0.0112
1/1 [=====] - 0s 2ms/step - loss: 0.0073 - bit_err:
0.0097
1/1 [=====] - 0s 2ms/step - loss: 0.0068 - bit_err:
0.0093
1/1 [=====] - 0s 2ms/step - loss: 0.0067 - bit_err:
0.0091

```





CP = 16, P = 64, activation = relu, lr = 0.004

```
[15]: run_all(16, 64, "relu", 0.004)
```

Epoch 1/100

250/250 - 48s - loss: 0.1174 - bit_err: 0.1773 - val_loss: 0.0468 - val_bit_err: 0.0638

Epoch 2/100

250/250 - 47s - loss: 0.0435 - bit_err: 0.0577 - val_loss: 0.0275 - val_bit_err: 0.0353

Epoch 3/100

250/250 - 48s - loss: 0.0301 - bit_err: 0.0388 - val_loss: 0.0285 - val_bit_err: 0.0350

Epoch 4/100

250/250 - 48s - loss: 0.0241 - bit_err: 0.0307 - val_loss: 0.0186 - val_bit_err: 0.0244

Epoch 5/100

250/250 - 48s - loss: 0.0206 - bit_err: 0.0258 - val_loss: 0.0201 - val_bit_err: 0.0242

Epoch 6/100

250/250 - 48s - loss: 0.0182 - bit_err: 0.0225 - val_loss: 0.0150 - val_bit_err: 0.0184

Epoch 7/100

250/250 - 48s - loss: 0.0165 - bit_err: 0.0199 - val_loss: 0.0159 - val_bit_err: 0.0188

Epoch 8/100

250/250 - 48s - loss: 0.0156 - bit_err: 0.0185 - val_loss: 0.0162 - val_bit_err: 0.0190

Epoch 9/100

250/250 - 48s - loss: 0.0150 - bit_err: 0.0174 - val_loss: 0.0107 - val_bit_err: 0.0123

Epoch 10/100

250/250 - 48s - loss: 0.0147 - bit_err: 0.0166 - val_loss: 0.0169 - val_bit_err: 0.0186

Epoch 11/100

250/250 - 48s - loss: 0.0146 - bit_err: 0.0163 - val_loss: 0.0135 - val_bit_err: 0.0147

Epoch 12/100

250/250 - 48s - loss: 0.0149 - bit_err: 0.0163 - val_loss: 0.0146 - val_bit_err: 0.0161

Epoch 13/100

250/250 - 48s - loss: 0.0150 - bit_err: 0.0162 - val_loss: 0.0183 - val_bit_err: 0.0194

Epoch 14/100

250/250 - 48s - loss: 0.0152 - bit_err: 0.0162 - val_loss: 0.0184 - val_bit_err: 0.0191

Epoch 15/100

250/250 - 47s - loss: 0.0155 - bit_err: 0.0164 - val_loss: 0.0128 - val_bit_err:

0.0136

Epoch 16/100
 250/250 - 47s - loss: 0.0157 - bit_err: 0.0164 - val_loss: 0.0161 - val_bit_err: 0.0166

Epoch 17/100
 250/250 - 47s - loss: 0.0160 - bit_err: 0.0166 - val_loss: 0.0190 - val_bit_err: 0.0199

Epoch 18/100
 250/250 - 48s - loss: 0.0162 - bit_err: 0.0167 - val_loss: 0.0179 - val_bit_err: 0.0182

Epoch 19/100
 250/250 - 48s - loss: 0.0164 - bit_err: 0.0169 - val_loss: 0.0173 - val_bit_err: 0.0178

Epoch 20/100
 250/250 - 49s - loss: 0.0169 - bit_err: 0.0174 - val_loss: 0.0186 - val_bit_err: 0.0190

Epoch 21/100
 250/250 - 48s - loss: 0.0170 - bit_err: 0.0174 - val_loss: 0.0144 - val_bit_err: 0.0148

Epoch 22/100
 250/250 - 48s - loss: 0.0169 - bit_err: 0.0172 - val_loss: 0.0184 - val_bit_err: 0.0188

Epoch 23/100
 250/250 - 48s - loss: 0.0171 - bit_err: 0.0174 - val_loss: 0.0162 - val_bit_err: 0.0166

Epoch 24/100
 250/250 - 48s - loss: 0.0174 - bit_err: 0.0177 - val_loss: 0.0137 - val_bit_err: 0.0139

Epoch 25/100
 250/250 - 47s - loss: 0.0177 - bit_err: 0.0179 - val_loss: 0.0162 - val_bit_err: 0.0165

Epoch 26/100
 250/250 - 48s - loss: 0.0180 - bit_err: 0.0183 - val_loss: 0.0204 - val_bit_err: 0.0208

Epoch 27/100
 250/250 - 47s - loss: 0.0184 - bit_err: 0.0186 - val_loss: 0.0217 - val_bit_err: 0.0220

Epoch 28/100
 250/250 - 48s - loss: 0.0187 - bit_err: 0.0190 - val_loss: 0.0180 - val_bit_err: 0.0183

Epoch 29/100
 250/250 - 47s - loss: 0.0190 - bit_err: 0.0193 - val_loss: 0.0160 - val_bit_err: 0.0161

Epoch 30/100
 250/250 - 47s - loss: 0.0184 - bit_err: 0.0186 - val_loss: 0.0170 - val_bit_err: 0.0173

Epoch 31/100
 250/250 - 47s - loss: 0.0184 - bit_err: 0.0186 - val_loss: 0.0216 - val_bit_err:

0.0217
Epoch 32/100
250/250 - 47s - loss: 0.0191 - bit_err: 0.0193 - val_loss: 0.0220 - val_bit_err: 0.0223
Epoch 33/100
250/250 - 47s - loss: 0.0191 - bit_err: 0.0192 - val_loss: 0.0212 - val_bit_err: 0.0214
Epoch 34/100
250/250 - 47s - loss: 0.0192 - bit_err: 0.0194 - val_loss: 0.0199 - val_bit_err: 0.0199
Epoch 35/100
250/250 - 47s - loss: 0.0192 - bit_err: 0.0193 - val_loss: 0.0174 - val_bit_err: 0.0174
Epoch 36/100
250/250 - 47s - loss: 0.0194 - bit_err: 0.0195 - val_loss: 0.0207 - val_bit_err: 0.0209
Epoch 37/100
250/250 - 47s - loss: 0.0197 - bit_err: 0.0198 - val_loss: 0.0196 - val_bit_err: 0.0197
Epoch 38/100
250/250 - 48s - loss: 0.0196 - bit_err: 0.0198 - val_loss: 0.0167 - val_bit_err: 0.0168
Epoch 39/100
250/250 - 48s - loss: 0.0199 - bit_err: 0.0200 - val_loss: 0.0204 - val_bit_err: 0.0205
Epoch 40/100
250/250 - 47s - loss: 0.0204 - bit_err: 0.0205 - val_loss: 0.0222 - val_bit_err: 0.0223
Epoch 41/100
250/250 - 48s - loss: 0.0199 - bit_err: 0.0201 - val_loss: 0.0189 - val_bit_err: 0.0189
Epoch 42/100
250/250 - 47s - loss: 0.0199 - bit_err: 0.0200 - val_loss: 0.0184 - val_bit_err: 0.0185
Epoch 43/100
250/250 - 47s - loss: 0.0203 - bit_err: 0.0204 - val_loss: 0.0205 - val_bit_err: 0.0207
Epoch 44/100
250/250 - 47s - loss: 0.0207 - bit_err: 0.0208 - val_loss: 0.0183 - val_bit_err: 0.0184
Epoch 45/100
250/250 - 48s - loss: 0.0209 - bit_err: 0.0210 - val_loss: 0.0218 - val_bit_err: 0.0218
Epoch 46/100
250/250 - 47s - loss: 0.0209 - bit_err: 0.0210 - val_loss: 0.0201 - val_bit_err: 0.0201
Epoch 47/100
250/250 - 48s - loss: 0.0204 - bit_err: 0.0205 - val_loss: 0.0206 - val_bit_err:

0.0207
Epoch 48/100
250/250 - 47s - loss: 0.0202 - bit_err: 0.0203 - val_loss: 0.0207 - val_bit_err:
0.0208
Epoch 49/100
250/250 - 48s - loss: 0.0206 - bit_err: 0.0206 - val_loss: 0.0192 - val_bit_err:
0.0192
Epoch 50/100
250/250 - 47s - loss: 0.0211 - bit_err: 0.0212 - val_loss: 0.0203 - val_bit_err:
0.0204
Epoch 51/100
250/250 - 47s - loss: 0.0209 - bit_err: 0.0210 - val_loss: 0.0197 - val_bit_err:
0.0197
Epoch 52/100
250/250 - 47s - loss: 0.0218 - bit_err: 0.0219 - val_loss: 0.0181 - val_bit_err:
0.0182
Epoch 53/100
250/250 - 47s - loss: 0.0210 - bit_err: 0.0211 - val_loss: 0.0219 - val_bit_err:
0.0220
Epoch 54/100
250/250 - 48s - loss: 0.0212 - bit_err: 0.0212 - val_loss: 0.0209 - val_bit_err:
0.0209
Epoch 55/100
250/250 - 47s - loss: 0.0212 - bit_err: 0.0213 - val_loss: 0.0220 - val_bit_err:
0.0220
Epoch 56/100
250/250 - 48s - loss: 0.0212 - bit_err: 0.0213 - val_loss: 0.0253 - val_bit_err:
0.0254
Epoch 57/100
250/250 - 47s - loss: 0.0216 - bit_err: 0.0217 - val_loss: 0.0226 - val_bit_err:
0.0227
Epoch 58/100
250/250 - 48s - loss: 0.0209 - bit_err: 0.0210 - val_loss: 0.0224 - val_bit_err:
0.0224
Epoch 59/100
250/250 - 47s - loss: 0.0214 - bit_err: 0.0215 - val_loss: 0.0228 - val_bit_err:
0.0228
Epoch 60/100
250/250 - 48s - loss: 0.0208 - bit_err: 0.0209 - val_loss: 0.0194 - val_bit_err:
0.0195
Epoch 61/100
250/250 - 48s - loss: 0.0219 - bit_err: 0.0219 - val_loss: 0.0195 - val_bit_err:
0.0196
Epoch 62/100
250/250 - 47s - loss: 0.0210 - bit_err: 0.0211 - val_loss: 0.0185 - val_bit_err:
0.0185
Epoch 63/100
250/250 - 47s - loss: 0.0208 - bit_err: 0.0209 - val_loss: 0.0210 - val_bit_err:

0.0210
Epoch 64/100
250/250 - 47s - loss: 0.0209 - bit_err: 0.0209 - val_loss: 0.0239 - val_bit_err:
0.0240
Epoch 65/100
250/250 - 47s - loss: 0.0220 - bit_err: 0.0221 - val_loss: 0.0224 - val_bit_err:
0.0225
Epoch 66/100
250/250 - 47s - loss: 0.0216 - bit_err: 0.0217 - val_loss: 0.0211 - val_bit_err:
0.0211
Epoch 67/100
250/250 - 48s - loss: 0.0220 - bit_err: 0.0221 - val_loss: 0.0217 - val_bit_err:
0.0217
Epoch 68/100
250/250 - 48s - loss: 0.0227 - bit_err: 0.0227 - val_loss: 0.0228 - val_bit_err:
0.0228
Epoch 69/100
250/250 - 48s - loss: 0.0223 - bit_err: 0.0224 - val_loss: 0.0246 - val_bit_err:
0.0246
Epoch 70/100
250/250 - 48s - loss: 0.0231 - bit_err: 0.0231 - val_loss: 0.0236 - val_bit_err:
0.0236
Epoch 71/100
250/250 - 47s - loss: 0.0223 - bit_err: 0.0223 - val_loss: 0.0231 - val_bit_err:
0.0231
Epoch 72/100
250/250 - 48s - loss: 0.0224 - bit_err: 0.0225 - val_loss: 0.0211 - val_bit_err:
0.0213
Epoch 73/100
250/250 - 47s - loss: 0.0223 - bit_err: 0.0224 - val_loss: 0.0176 - val_bit_err:
0.0176
Epoch 74/100
250/250 - 47s - loss: 0.0221 - bit_err: 0.0222 - val_loss: 0.0230 - val_bit_err:
0.0230
Epoch 75/100
250/250 - 48s - loss: 0.0228 - bit_err: 0.0228 - val_loss: 0.0246 - val_bit_err:
0.0246
Epoch 76/100
250/250 - 47s - loss: 0.0219 - bit_err: 0.0219 - val_loss: 0.0200 - val_bit_err:
0.0201
Epoch 77/100
250/250 - 47s - loss: 0.0226 - bit_err: 0.0227 - val_loss: 0.0212 - val_bit_err:
0.0213
Epoch 78/100
250/250 - 47s - loss: 0.0227 - bit_err: 0.0227 - val_loss: 0.0247 - val_bit_err:
0.0247
Epoch 79/100
250/250 - 47s - loss: 0.0226 - bit_err: 0.0227 - val_loss: 0.0226 - val_bit_err:

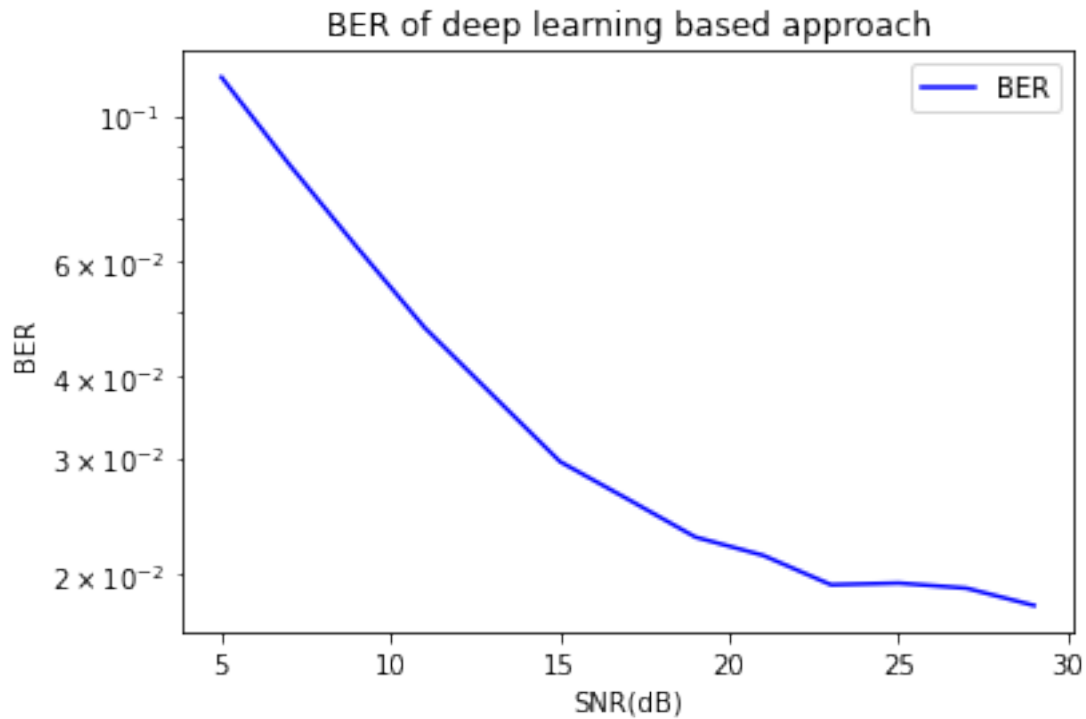
0.0226
Epoch 80/100
250/250 - 47s - loss: 0.0228 - bit_err: 0.0228 - val_loss: 0.0219 - val_bit_err:
0.0220
Epoch 81/100
250/250 - 47s - loss: 0.0226 - bit_err: 0.0226 - val_loss: 0.0265 - val_bit_err:
0.0266
Epoch 82/100
250/250 - 47s - loss: 0.0226 - bit_err: 0.0227 - val_loss: 0.0207 - val_bit_err:
0.0207
Epoch 83/100
250/250 - 47s - loss: 0.0226 - bit_err: 0.0226 - val_loss: 0.0248 - val_bit_err:
0.0249
Epoch 84/100
250/250 - 47s - loss: 0.0229 - bit_err: 0.0230 - val_loss: 0.0217 - val_bit_err:
0.0217
Epoch 85/100
250/250 - 47s - loss: 0.0225 - bit_err: 0.0225 - val_loss: 0.0252 - val_bit_err:
0.0253
Epoch 86/100
250/250 - 48s - loss: 0.0223 - bit_err: 0.0224 - val_loss: 0.0175 - val_bit_err:
0.0175
Epoch 87/100
250/250 - 47s - loss: 0.0226 - bit_err: 0.0226 - val_loss: 0.0219 - val_bit_err:
0.0219
Epoch 88/100
250/250 - 47s - loss: 0.0225 - bit_err: 0.0226 - val_loss: 0.0265 - val_bit_err:
0.0266
Epoch 89/100
250/250 - 47s - loss: 0.0233 - bit_err: 0.0234 - val_loss: 0.0223 - val_bit_err:
0.0224
Epoch 90/100
250/250 - 47s - loss: 0.0226 - bit_err: 0.0227 - val_loss: 0.0228 - val_bit_err:
0.0229
Epoch 91/100
250/250 - 47s - loss: 0.0234 - bit_err: 0.0235 - val_loss: 0.0259 - val_bit_err:
0.0259
Epoch 92/100
250/250 - 47s - loss: 0.0238 - bit_err: 0.0239 - val_loss: 0.0286 - val_bit_err:
0.0286
Epoch 93/100
250/250 - 47s - loss: 0.0241 - bit_err: 0.0242 - val_loss: 0.0257 - val_bit_err:
0.0257
Epoch 94/100
250/250 - 47s - loss: 0.0234 - bit_err: 0.0234 - val_loss: 0.0239 - val_bit_err:
0.0239
Epoch 95/100
250/250 - 47s - loss: 0.0236 - bit_err: 0.0236 - val_loss: 0.0262 - val_bit_err:

```

0.0263
Epoch 96/100
250/250 - 47s - loss: 0.0235 - bit_err: 0.0235 - val_loss: 0.0232 - val_bit_err:
0.0232
Epoch 97/100
250/250 - 48s - loss: 0.0231 - bit_err: 0.0231 - val_loss: 0.0232 - val_bit_err:
0.0232
Epoch 98/100
250/250 - 48s - loss: 0.0232 - bit_err: 0.0232 - val_loss: 0.0242 - val_bit_err:
0.0242
Epoch 99/100
250/250 - 48s - loss: 0.0244 - bit_err: 0.0244 - val_loss: 0.0257 - val_bit_err:
0.0257
Epoch 100/100
250/250 - 47s - loss: 0.0235 - bit_err: 0.0235 - val_loss: 0.0216 - val_bit_err:
0.0217
1/1 [=====] - 0s 1ms/step - loss: 0.1143 - bit_err:
0.1144
1/1 [=====] - 0s 2ms/step - loss: 0.0841 - bit_err:
0.0842
1/1 [=====] - 0s 2ms/step - loss: 0.0629 - bit_err:
0.0629
1/1 [=====] - 0s 2ms/step - loss: 0.0474 - bit_err:
0.0474
1/1 [=====] - 0s 2ms/step - loss: 0.0374 - bit_err:
0.0374
1/1 [=====] - 0s 2ms/step - loss: 0.0296 - bit_err:
0.0296
1/1 [=====] - 0s 2ms/step - loss: 0.0259 - bit_err:
0.0260
1/1 [=====] - 0s 2ms/step - loss: 0.0227 - bit_err:
0.0227
1/1 [=====] - 0s 1ms/step - loss: 0.0212 - bit_err:
0.0213
1/1 [=====] - 0s 2ms/step - loss: 0.0192 - bit_err:
0.0192
1/1 [=====] - 0s 2ms/step - loss: 0.0193 - bit_err:
0.0193
1/1 [=====] - 0s 2ms/step - loss: 0.0189 - bit_err:
0.0190
1/1 [=====] - 0s 2ms/step - loss: 0.0178 - bit_err:
0.0179

```





CP = 16, P = 8, activation = relu, lr = 0.004

```
[16]: run_all(16, 8, "relu", 0.004)
```

Epoch 1/100

250/250 - 48s - loss: 0.1261 - bit_err: 0.1963 - val_loss: 0.0595 - val_bit_err: 0.0842

Epoch 2/100

250/250 - 48s - loss: 0.0497 - bit_err: 0.0685 - val_loss: 0.0406 - val_bit_err: 0.0571

Epoch 3/100

250/250 - 48s - loss: 0.0364 - bit_err: 0.0494 - val_loss: 0.0296 - val_bit_err: 0.0406

Epoch 4/100

250/250 - 48s - loss: 0.0294 - bit_err: 0.0392 - val_loss: 0.0399 - val_bit_err: 0.0494

Epoch 5/100

250/250 - 48s - loss: 0.0262 - bit_err: 0.0344 - val_loss: 0.0241 - val_bit_err: 0.0318

Epoch 6/100

250/250 - 48s - loss: 0.0237 - bit_err: 0.0307 - val_loss: 0.0234 - val_bit_err: 0.0297

Epoch 7/100

250/250 - 48s - loss: 0.0223 - bit_err: 0.0284 - val_loss: 0.0188 - val_bit_err:

0.0247
Epoch 8/100
250/250 - 48s - loss: 0.0209 - bit_err: 0.0262 - val_loss: 0.0243 - val_bit_err:
0.0303
Epoch 9/100
250/250 - 48s - loss: 0.0203 - bit_err: 0.0252 - val_loss: 0.0196 - val_bit_err:
0.0241
Epoch 10/100
250/250 - 48s - loss: 0.0197 - bit_err: 0.0241 - val_loss: 0.0210 - val_bit_err:
0.0253
Epoch 11/100
250/250 - 48s - loss: 0.0195 - bit_err: 0.0233 - val_loss: 0.0203 - val_bit_err:
0.0247
Epoch 12/100
250/250 - 48s - loss: 0.0190 - bit_err: 0.0225 - val_loss: 0.0190 - val_bit_err:
0.0225
Epoch 13/100
250/250 - 48s - loss: 0.0190 - bit_err: 0.0221 - val_loss: 0.0203 - val_bit_err:
0.0234
Epoch 14/100
250/250 - 48s - loss: 0.0188 - bit_err: 0.0216 - val_loss: 0.0215 - val_bit_err:
0.0242
Epoch 15/100
250/250 - 48s - loss: 0.0189 - bit_err: 0.0214 - val_loss: 0.0224 - val_bit_err:
0.0253
Epoch 16/100
250/250 - 48s - loss: 0.0190 - bit_err: 0.0213 - val_loss: 0.0188 - val_bit_err:
0.0213
Epoch 17/100
250/250 - 48s - loss: 0.0194 - bit_err: 0.0215 - val_loss: 0.0190 - val_bit_err:
0.0206
Epoch 18/100
250/250 - 48s - loss: 0.0195 - bit_err: 0.0212 - val_loss: 0.0177 - val_bit_err:
0.0196
Epoch 19/100
250/250 - 48s - loss: 0.0196 - bit_err: 0.0212 - val_loss: 0.0184 - val_bit_err:
0.0194
Epoch 20/100
250/250 - 48s - loss: 0.0199 - bit_err: 0.0213 - val_loss: 0.0211 - val_bit_err:
0.0222
Epoch 21/100
250/250 - 48s - loss: 0.0202 - bit_err: 0.0214 - val_loss: 0.0196 - val_bit_err:
0.0204
Epoch 22/100
250/250 - 48s - loss: 0.0204 - bit_err: 0.0214 - val_loss: 0.0236 - val_bit_err:
0.0243
Epoch 23/100
250/250 - 48s - loss: 0.0206 - bit_err: 0.0216 - val_loss: 0.0194 - val_bit_err:

0.0201
Epoch 24/100
250/250 - 47s - loss: 0.0209 - bit_err: 0.0217 - val_loss: 0.0234 - val_bit_err:
0.0244
Epoch 25/100
250/250 - 48s - loss: 0.0208 - bit_err: 0.0216 - val_loss: 0.0198 - val_bit_err:
0.0203
Epoch 26/100
250/250 - 47s - loss: 0.0210 - bit_err: 0.0218 - val_loss: 0.0208 - val_bit_err:
0.0215
Epoch 27/100
250/250 - 48s - loss: 0.0215 - bit_err: 0.0222 - val_loss: 0.0218 - val_bit_err:
0.0225
Epoch 28/100
250/250 - 48s - loss: 0.0219 - bit_err: 0.0225 - val_loss: 0.0229 - val_bit_err:
0.0234
Epoch 29/100
250/250 - 47s - loss: 0.0220 - bit_err: 0.0226 - val_loss: 0.0217 - val_bit_err:
0.0224
Epoch 30/100
250/250 - 47s - loss: 0.0224 - bit_err: 0.0229 - val_loss: 0.0243 - val_bit_err:
0.0247
Epoch 31/100
250/250 - 48s - loss: 0.0224 - bit_err: 0.0229 - val_loss: 0.0265 - val_bit_err:
0.0270
Epoch 32/100
250/250 - 48s - loss: 0.0229 - bit_err: 0.0233 - val_loss: 0.0207 - val_bit_err:
0.0211
Epoch 33/100
250/250 - 48s - loss: 0.0230 - bit_err: 0.0233 - val_loss: 0.0254 - val_bit_err:
0.0258
Epoch 34/100
250/250 - 47s - loss: 0.0231 - bit_err: 0.0235 - val_loss: 0.0248 - val_bit_err:
0.0253
Epoch 35/100
250/250 - 48s - loss: 0.0227 - bit_err: 0.0231 - val_loss: 0.0210 - val_bit_err:
0.0211
Epoch 36/100
250/250 - 48s - loss: 0.0232 - bit_err: 0.0235 - val_loss: 0.0219 - val_bit_err:
0.0223
Epoch 37/100
250/250 - 47s - loss: 0.0236 - bit_err: 0.0239 - val_loss: 0.0211 - val_bit_err:
0.0215
Epoch 38/100
250/250 - 48s - loss: 0.0237 - bit_err: 0.0240 - val_loss: 0.0251 - val_bit_err:
0.0254
Epoch 39/100
250/250 - 47s - loss: 0.0237 - bit_err: 0.0240 - val_loss: 0.0226 - val_bit_err:

0.0228
Epoch 40/100
250/250 - 48s - loss: 0.0239 - bit_err: 0.0241 - val_loss: 0.0246 - val_bit_err: 0.0249
Epoch 41/100
250/250 - 47s - loss: 0.0239 - bit_err: 0.0242 - val_loss: 0.0253 - val_bit_err: 0.0254
Epoch 42/100
250/250 - 47s - loss: 0.0245 - bit_err: 0.0248 - val_loss: 0.0267 - val_bit_err: 0.0270
Epoch 43/100
250/250 - 48s - loss: 0.0245 - bit_err: 0.0248 - val_loss: 0.0251 - val_bit_err: 0.0253
Epoch 44/100
250/250 - 47s - loss: 0.0249 - bit_err: 0.0251 - val_loss: 0.0249 - val_bit_err: 0.0253
Epoch 45/100
250/250 - 48s - loss: 0.0249 - bit_err: 0.0251 - val_loss: 0.0292 - val_bit_err: 0.0293
Epoch 46/100
250/250 - 47s - loss: 0.0249 - bit_err: 0.0251 - val_loss: 0.0280 - val_bit_err: 0.0283
Epoch 47/100
250/250 - 48s - loss: 0.0249 - bit_err: 0.0251 - val_loss: 0.0223 - val_bit_err: 0.0226
Epoch 48/100
250/250 - 47s - loss: 0.0252 - bit_err: 0.0254 - val_loss: 0.0271 - val_bit_err: 0.0272
Epoch 49/100
250/250 - 47s - loss: 0.0252 - bit_err: 0.0253 - val_loss: 0.0286 - val_bit_err: 0.0288
Epoch 50/100
250/250 - 47s - loss: 0.0253 - bit_err: 0.0255 - val_loss: 0.0210 - val_bit_err: 0.0211
Epoch 51/100
250/250 - 48s - loss: 0.0254 - bit_err: 0.0256 - val_loss: 0.0249 - val_bit_err: 0.0251
Epoch 52/100
250/250 - 47s - loss: 0.0252 - bit_err: 0.0254 - val_loss: 0.0264 - val_bit_err: 0.0265
Epoch 53/100
250/250 - 48s - loss: 0.0252 - bit_err: 0.0254 - val_loss: 0.0269 - val_bit_err: 0.0270
Epoch 54/100
250/250 - 48s - loss: 0.0259 - bit_err: 0.0260 - val_loss: 0.0284 - val_bit_err: 0.0285
Epoch 55/100
250/250 - 48s - loss: 0.0259 - bit_err: 0.0260 - val_loss: 0.0249 - val_bit_err:

0.0251
Epoch 56/100
250/250 - 48s - loss: 0.0262 - bit_err: 0.0264 - val_loss: 0.0286 - val_bit_err:
0.0288
Epoch 57/100
250/250 - 48s - loss: 0.0256 - bit_err: 0.0258 - val_loss: 0.0280 - val_bit_err:
0.0281
Epoch 58/100
250/250 - 48s - loss: 0.0257 - bit_err: 0.0258 - val_loss: 0.0285 - val_bit_err:
0.0286
Epoch 59/100
250/250 - 48s - loss: 0.0260 - bit_err: 0.0261 - val_loss: 0.0261 - val_bit_err:
0.0264
Epoch 60/100
250/250 - 47s - loss: 0.0260 - bit_err: 0.0261 - val_loss: 0.0218 - val_bit_err:
0.0218
Epoch 61/100
250/250 - 48s - loss: 0.0262 - bit_err: 0.0263 - val_loss: 0.0257 - val_bit_err:
0.0258
Epoch 62/100
250/250 - 48s - loss: 0.0264 - bit_err: 0.0265 - val_loss: 0.0265 - val_bit_err:
0.0266
Epoch 63/100
250/250 - 47s - loss: 0.0261 - bit_err: 0.0262 - val_loss: 0.0287 - val_bit_err:
0.0287
Epoch 64/100
250/250 - 48s - loss: 0.0269 - bit_err: 0.0270 - val_loss: 0.0272 - val_bit_err:
0.0272
Epoch 65/100
250/250 - 48s - loss: 0.0268 - bit_err: 0.0269 - val_loss: 0.0239 - val_bit_err:
0.0239
Epoch 66/100
250/250 - 48s - loss: 0.0262 - bit_err: 0.0263 - val_loss: 0.0263 - val_bit_err:
0.0263
Epoch 67/100
250/250 - 48s - loss: 0.0264 - bit_err: 0.0265 - val_loss: 0.0255 - val_bit_err:
0.0256
Epoch 68/100
250/250 - 47s - loss: 0.0269 - bit_err: 0.0270 - val_loss: 0.0227 - val_bit_err:
0.0229
Epoch 69/100
250/250 - 48s - loss: 0.0271 - bit_err: 0.0272 - val_loss: 0.0261 - val_bit_err:
0.0261
Epoch 70/100
250/250 - 48s - loss: 0.0267 - bit_err: 0.0268 - val_loss: 0.0266 - val_bit_err:
0.0267
Epoch 71/100
250/250 - 48s - loss: 0.0270 - bit_err: 0.0271 - val_loss: 0.0242 - val_bit_err:

0.0242
Epoch 72/100
250/250 - 48s - loss: 0.0276 - bit_err: 0.0277 - val_loss: 0.0243 - val_bit_err:
0.0244
Epoch 73/100
250/250 - 47s - loss: 0.0268 - bit_err: 0.0268 - val_loss: 0.0300 - val_bit_err:
0.0301
Epoch 74/100
250/250 - 47s - loss: 0.0268 - bit_err: 0.0269 - val_loss: 0.0257 - val_bit_err:
0.0257
Epoch 75/100
250/250 - 47s - loss: 0.0268 - bit_err: 0.0269 - val_loss: 0.0271 - val_bit_err:
0.0272
Epoch 76/100
250/250 - 47s - loss: 0.0268 - bit_err: 0.0269 - val_loss: 0.0249 - val_bit_err:
0.0250
Epoch 77/100
250/250 - 47s - loss: 0.0274 - bit_err: 0.0275 - val_loss: 0.0313 - val_bit_err:
0.0313
Epoch 78/100
250/250 - 47s - loss: 0.0274 - bit_err: 0.0275 - val_loss: 0.0278 - val_bit_err:
0.0278
Epoch 79/100
250/250 - 47s - loss: 0.0274 - bit_err: 0.0275 - val_loss: 0.0268 - val_bit_err:
0.0269
Epoch 80/100
250/250 - 47s - loss: 0.0274 - bit_err: 0.0275 - val_loss: 0.0286 - val_bit_err:
0.0287
Epoch 81/100
250/250 - 48s - loss: 0.0273 - bit_err: 0.0273 - val_loss: 0.0268 - val_bit_err:
0.0268
Epoch 82/100
250/250 - 47s - loss: 0.0276 - bit_err: 0.0277 - val_loss: 0.0295 - val_bit_err:
0.0295
Epoch 83/100
250/250 - 47s - loss: 0.0274 - bit_err: 0.0275 - val_loss: 0.0233 - val_bit_err:
0.0233
Epoch 84/100
250/250 - 47s - loss: 0.0280 - bit_err: 0.0281 - val_loss: 0.0231 - val_bit_err:
0.0231
Epoch 85/100
250/250 - 48s - loss: 0.0275 - bit_err: 0.0275 - val_loss: 0.0342 - val_bit_err:
0.0343
Epoch 86/100
250/250 - 48s - loss: 0.0274 - bit_err: 0.0275 - val_loss: 0.0307 - val_bit_err:
0.0308
Epoch 87/100
250/250 - 47s - loss: 0.0281 - bit_err: 0.0282 - val_loss: 0.0265 - val_bit_err:

```

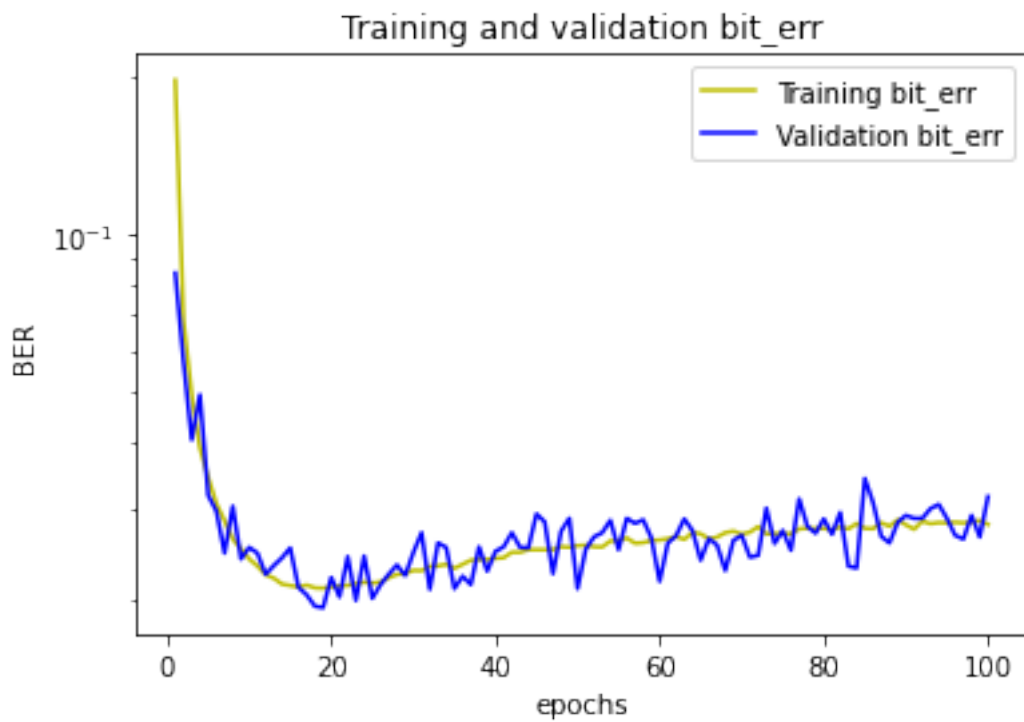
0.0266
Epoch 88/100
250/250 - 48s - loss: 0.0277 - bit_err: 0.0278 - val_loss: 0.0258 - val_bit_err:
0.0258
Epoch 89/100
250/250 - 48s - loss: 0.0285 - bit_err: 0.0286 - val_loss: 0.0282 - val_bit_err:
0.0282
Epoch 90/100
250/250 - 48s - loss: 0.0279 - bit_err: 0.0279 - val_loss: 0.0291 - val_bit_err:
0.0291
Epoch 91/100
250/250 - 47s - loss: 0.0274 - bit_err: 0.0274 - val_loss: 0.0287 - val_bit_err:
0.0288
Epoch 92/100
250/250 - 47s - loss: 0.0283 - bit_err: 0.0284 - val_loss: 0.0287 - val_bit_err:
0.0288
Epoch 93/100
250/250 - 47s - loss: 0.0280 - bit_err: 0.0281 - val_loss: 0.0300 - val_bit_err:
0.0300
Epoch 94/100
250/250 - 47s - loss: 0.0282 - bit_err: 0.0282 - val_loss: 0.0305 - val_bit_err:
0.0306
Epoch 95/100
250/250 - 48s - loss: 0.0281 - bit_err: 0.0282 - val_loss: 0.0286 - val_bit_err:
0.0288
Epoch 96/100
250/250 - 48s - loss: 0.0282 - bit_err: 0.0283 - val_loss: 0.0266 - val_bit_err:
0.0267
Epoch 97/100
250/250 - 48s - loss: 0.0281 - bit_err: 0.0282 - val_loss: 0.0262 - val_bit_err:
0.0263
Epoch 98/100
250/250 - 48s - loss: 0.0282 - bit_err: 0.0283 - val_loss: 0.0290 - val_bit_err:
0.0291
Epoch 99/100
250/250 - 47s - loss: 0.0284 - bit_err: 0.0285 - val_loss: 0.0264 - val_bit_err:
0.0265
Epoch 100/100
250/250 - 47s - loss: 0.0279 - bit_err: 0.0280 - val_loss: 0.0315 - val_bit_err:
0.0316
1/1 [=====] - 0s 2ms/step - loss: 0.1585 - bit_err:
0.1586
1/1 [=====] - 0s 2ms/step - loss: 0.1156 - bit_err:
0.1157
1/1 [=====] - 0s 2ms/step - loss: 0.0881 - bit_err:
0.0882
1/1 [=====] - 0s 2ms/step - loss: 0.0670 - bit_err:
0.0671

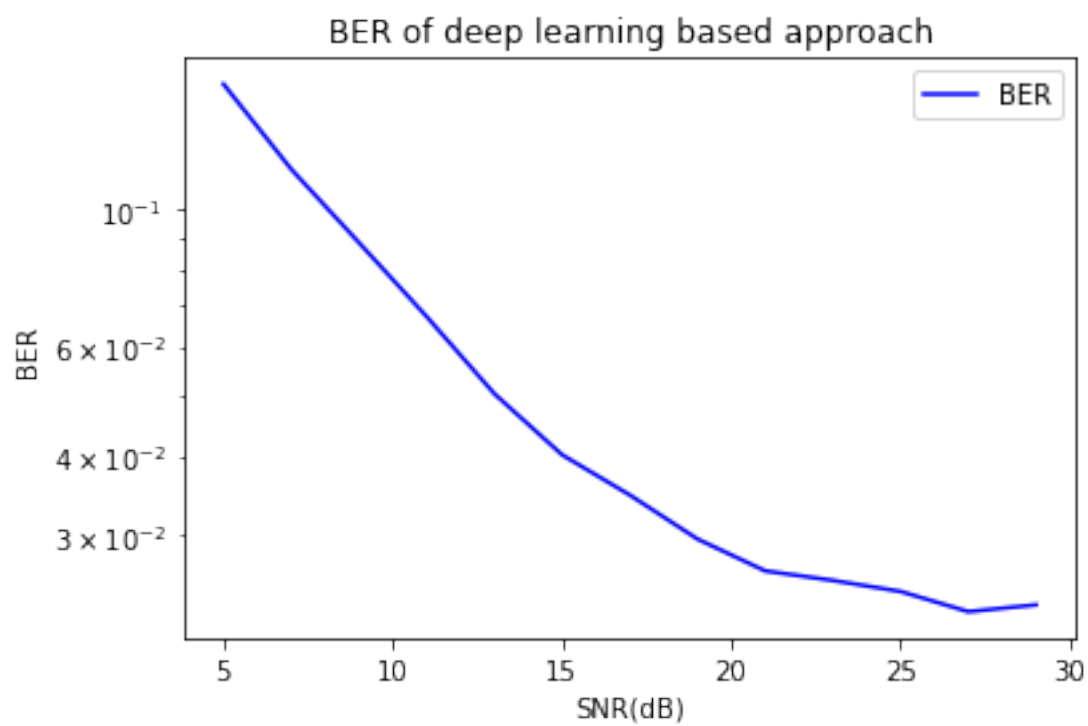
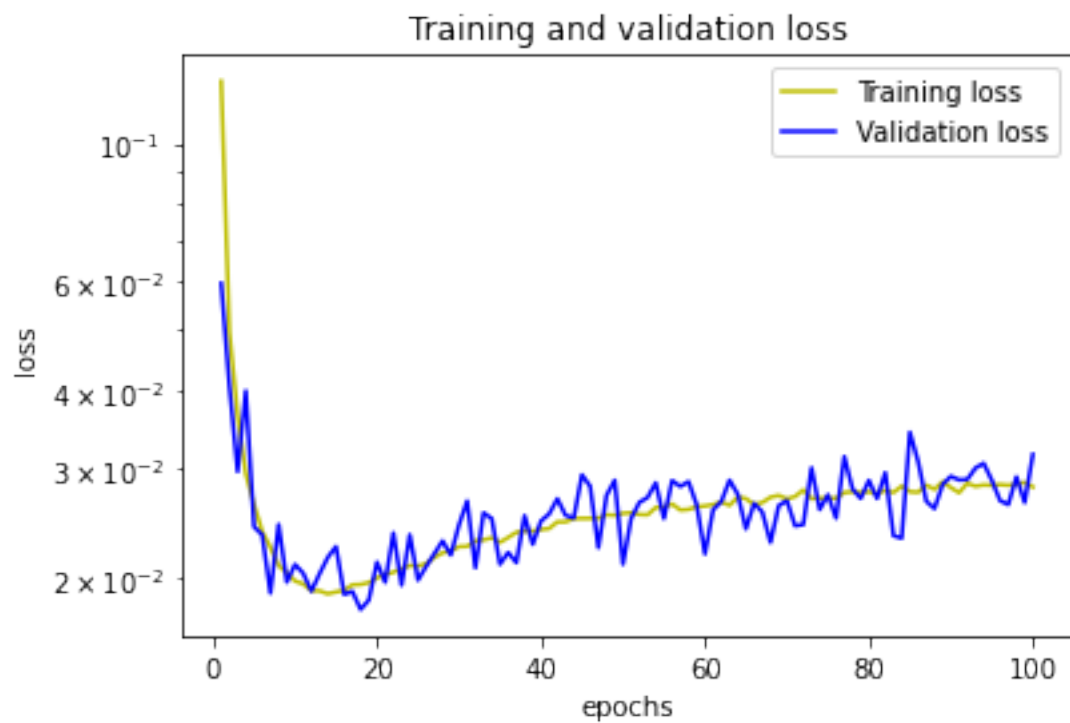
```

```

1/1 [=====] - 0s 2ms/step - loss: 0.0503 - bit_err:
0.0504
1/1 [=====] - 0s 2ms/step - loss: 0.0401 - bit_err:
0.0402
1/1 [=====] - 0s 2ms/step - loss: 0.0346 - bit_err:
0.0347
1/1 [=====] - 0s 2ms/step - loss: 0.0294 - bit_err:
0.0294
1/1 [=====] - 0s 2ms/step - loss: 0.0261 - bit_err:
0.0262
1/1 [=====] - 0s 2ms/step - loss: 0.0252 - bit_err:
0.0253
1/1 [=====] - 0s 1ms/step - loss: 0.0242 - bit_err:
0.0243
1/1 [=====] - 0s 2ms/step - loss: 0.0225 - bit_err:
0.0225
1/1 [=====] - 0s 2ms/step - loss: 0.0231 - bit_err:
0.0231

```





CP = 16, P = 64, activation = sigmoid, lr = 0.001

```
[17]: run_all(16, 64, "sigmoid", 0.001)
```

Epoch 1/100

250/250 - 44s - loss: 0.2470 - bit_err: 0.4619 - val_loss: 0.2305 - val_bit_err: 0.3438

Epoch 2/100

250/250 - 44s - loss: 0.1941 - bit_err: 0.2564 - val_loss: 0.1632 - val_bit_err: 0.2041

Epoch 3/100

250/250 - 44s - loss: 0.1327 - bit_err: 0.1449 - val_loss: 0.1068 - val_bit_err: 0.1018

Epoch 4/100

250/250 - 44s - loss: 0.0870 - bit_err: 0.0760 - val_loss: 0.0722 - val_bit_err: 0.0619

Epoch 5/100

250/250 - 44s - loss: 0.0566 - bit_err: 0.0448 - val_loss: 0.0478 - val_bit_err: 0.0403

Epoch 6/100

250/250 - 44s - loss: 0.0396 - bit_err: 0.0316 - val_loss: 0.0324 - val_bit_err: 0.0243

Epoch 7/100

250/250 - 44s - loss: 0.0287 - bit_err: 0.0227 - val_loss: 0.0251 - val_bit_err: 0.0213

Epoch 8/100

250/250 - 44s - loss: 0.0216 - bit_err: 0.0175 - val_loss: 0.0190 - val_bit_err: 0.0154

Epoch 9/100

250/250 - 44s - loss: 0.0170 - bit_err: 0.0143 - val_loss: 0.0158 - val_bit_err: 0.0139

Epoch 10/100

250/250 - 44s - loss: 0.0139 - bit_err: 0.0123 - val_loss: 0.0127 - val_bit_err: 0.0107

Epoch 11/100

250/250 - 44s - loss: 0.0117 - bit_err: 0.0108 - val_loss: 0.0111 - val_bit_err: 0.0101

Epoch 12/100

250/250 - 44s - loss: 0.0101 - bit_err: 0.0098 - val_loss: 0.0084 - val_bit_err: 0.0076

Epoch 13/100

250/250 - 44s - loss: 0.0089 - bit_err: 0.0089 - val_loss: 0.0094 - val_bit_err: 0.0102

Epoch 14/100

250/250 - 45s - loss: 0.0080 - bit_err: 0.0084 - val_loss: 0.0077 - val_bit_err: 0.0078

Epoch 15/100

250/250 - 44s - loss: 0.0074 - bit_err: 0.0079 - val_loss: 0.0072 - val_bit_err:

0.0079

Epoch 16/100
 250/250 - 45s - loss: 0.0068 - bit_err: 0.0075 - val_loss: 0.0064 - val_bit_err: 0.0068

Epoch 17/100
 250/250 - 44s - loss: 0.0063 - bit_err: 0.0071 - val_loss: 0.0064 - val_bit_err: 0.0073

Epoch 18/100
 250/250 - 45s - loss: 0.0060 - bit_err: 0.0069 - val_loss: 0.0061 - val_bit_err: 0.0065

Epoch 19/100
 250/250 - 46s - loss: 0.0057 - bit_err: 0.0067 - val_loss: 0.0053 - val_bit_err: 0.0062

Epoch 20/100
 250/250 - 46s - loss: 0.0054 - bit_err: 0.0064 - val_loss: 0.0054 - val_bit_err: 0.0064

Epoch 21/100
 250/250 - 47s - loss: 0.0052 - bit_err: 0.0063 - val_loss: 0.0059 - val_bit_err: 0.0077

Epoch 22/100
 250/250 - 48s - loss: 0.0050 - bit_err: 0.0061 - val_loss: 0.0043 - val_bit_err: 0.0053

Epoch 23/100
 250/250 - 48s - loss: 0.0048 - bit_err: 0.0060 - val_loss: 0.0046 - val_bit_err: 0.0058

Epoch 24/100
 250/250 - 48s - loss: 0.0047 - bit_err: 0.0058 - val_loss: 0.0045 - val_bit_err: 0.0056

Epoch 25/100
 250/250 - 48s - loss: 0.0046 - bit_err: 0.0058 - val_loss: 0.0048 - val_bit_err: 0.0063

Epoch 26/100
 250/250 - 48s - loss: 0.0045 - bit_err: 0.0057 - val_loss: 0.0051 - val_bit_err: 0.0068

Epoch 27/100
 250/250 - 48s - loss: 0.0044 - bit_err: 0.0056 - val_loss: 0.0050 - val_bit_err: 0.0067

Epoch 28/100
 250/250 - 48s - loss: 0.0043 - bit_err: 0.0055 - val_loss: 0.0037 - val_bit_err: 0.0043

Epoch 29/100
 250/250 - 48s - loss: 0.0042 - bit_err: 0.0054 - val_loss: 0.0049 - val_bit_err: 0.0066

Epoch 30/100
 250/250 - 48s - loss: 0.0041 - bit_err: 0.0054 - val_loss: 0.0038 - val_bit_err: 0.0049

Epoch 31/100
 250/250 - 48s - loss: 0.0041 - bit_err: 0.0053 - val_loss: 0.0033 - val_bit_err:

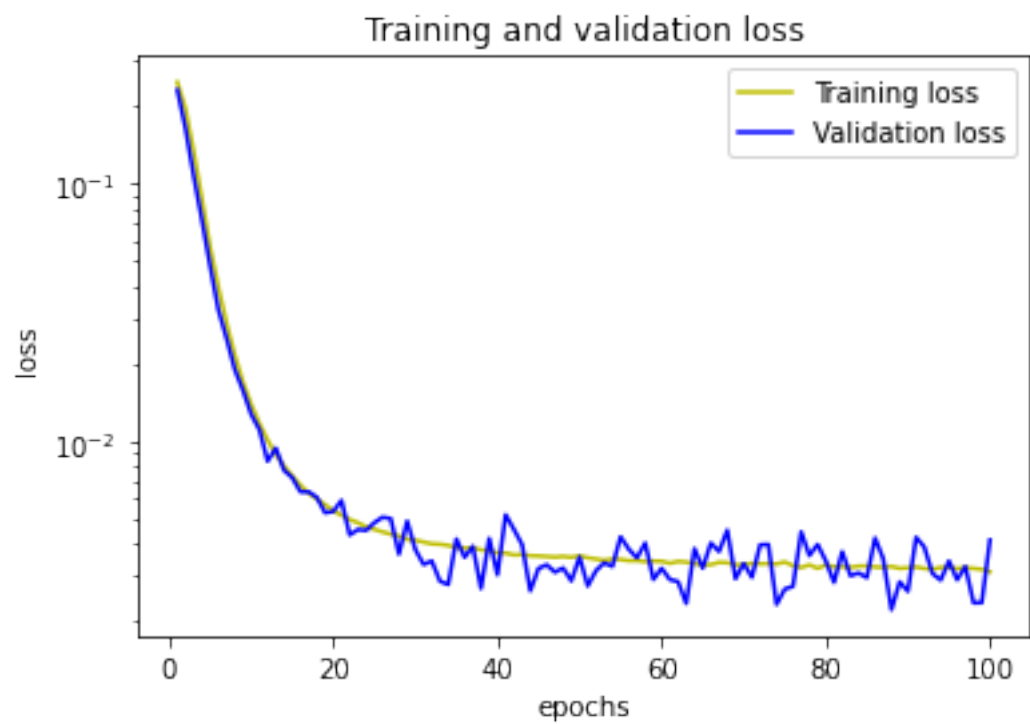
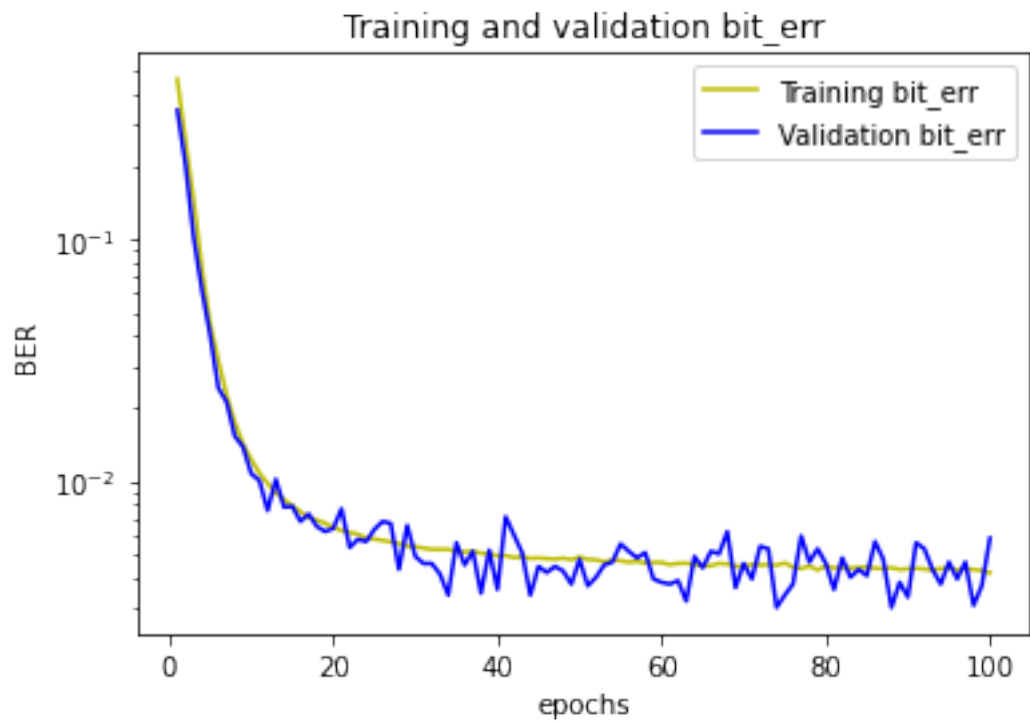
0.0046
Epoch 32/100
250/250 - 48s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0034 - val_bit_err:
0.0046
Epoch 33/100
250/250 - 48s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0029 - val_bit_err:
0.0041
Epoch 34/100
250/250 - 48s - loss: 0.0040 - bit_err: 0.0052 - val_loss: 0.0028 - val_bit_err:
0.0034
Epoch 35/100
250/250 - 48s - loss: 0.0039 - bit_err: 0.0051 - val_loss: 0.0042 - val_bit_err:
0.0056
Epoch 36/100
250/250 - 48s - loss: 0.0039 - bit_err: 0.0051 - val_loss: 0.0036 - val_bit_err:
0.0045
Epoch 37/100
250/250 - 48s - loss: 0.0039 - bit_err: 0.0051 - val_loss: 0.0039 - val_bit_err:
0.0051
Epoch 38/100
250/250 - 48s - loss: 0.0038 - bit_err: 0.0050 - val_loss: 0.0027 - val_bit_err:
0.0034
Epoch 39/100
250/250 - 48s - loss: 0.0038 - bit_err: 0.0050 - val_loss: 0.0042 - val_bit_err:
0.0052
Epoch 40/100
250/250 - 48s - loss: 0.0037 - bit_err: 0.0049 - val_loss: 0.0030 - val_bit_err:
0.0036
Epoch 41/100
250/250 - 48s - loss: 0.0037 - bit_err: 0.0049 - val_loss: 0.0052 - val_bit_err:
0.0071
Epoch 42/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0048 - val_loss: 0.0046 - val_bit_err:
0.0060
Epoch 43/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0049 - val_loss: 0.0040 - val_bit_err:
0.0051
Epoch 44/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0048 - val_loss: 0.0026 - val_bit_err:
0.0034
Epoch 45/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0048 - val_loss: 0.0032 - val_bit_err:
0.0044
Epoch 46/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0048 - val_loss: 0.0033 - val_bit_err:
0.0042
Epoch 47/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0048 - val_loss: 0.0031 - val_bit_err:

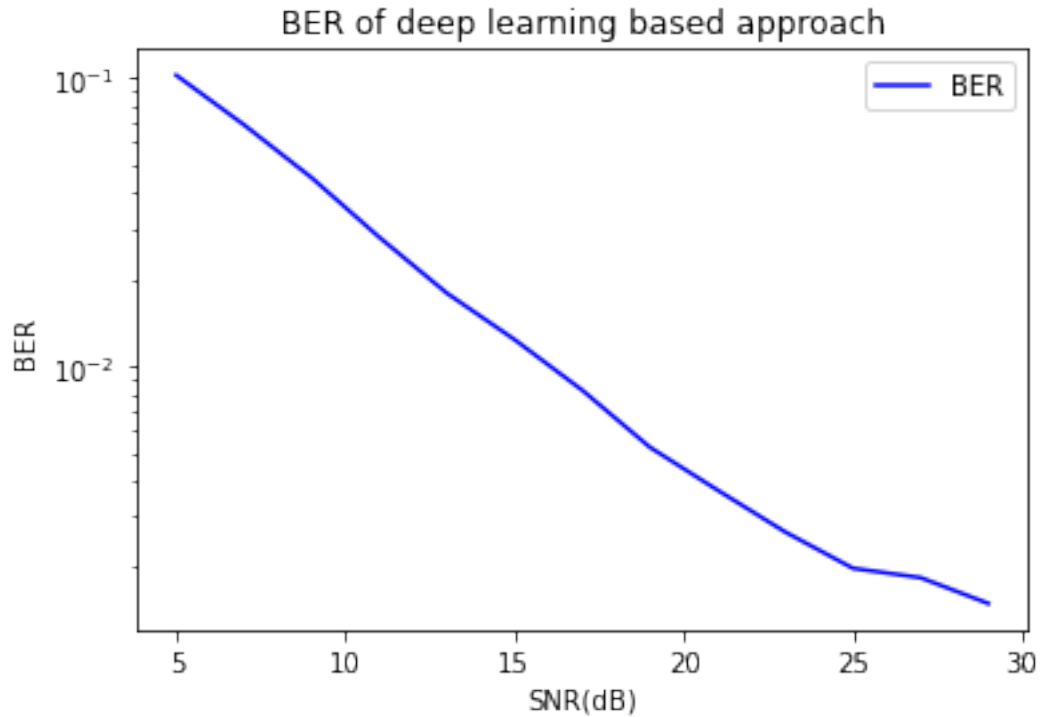
0.0044
Epoch 48/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0048 - val_loss: 0.0032 - val_bit_err: 0.0042
Epoch 49/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0047 - val_loss: 0.0029 - val_bit_err: 0.0038
Epoch 50/100
250/250 - 48s - loss: 0.0036 - bit_err: 0.0049 - val_loss: 0.0036 - val_bit_err: 0.0048
Epoch 51/100
250/250 - 48s - loss: 0.0035 - bit_err: 0.0047 - val_loss: 0.0028 - val_bit_err: 0.0037
Epoch 52/100
250/250 - 48s - loss: 0.0035 - bit_err: 0.0047 - val_loss: 0.0032 - val_bit_err: 0.0040
Epoch 53/100
250/250 - 48s - loss: 0.0035 - bit_err: 0.0046 - val_loss: 0.0034 - val_bit_err: 0.0045
Epoch 54/100
250/250 - 48s - loss: 0.0035 - bit_err: 0.0047 - val_loss: 0.0033 - val_bit_err: 0.0046
Epoch 55/100
250/250 - 48s - loss: 0.0035 - bit_err: 0.0047 - val_loss: 0.0043 - val_bit_err: 0.0055
Epoch 56/100
250/250 - 48s - loss: 0.0035 - bit_err: 0.0046 - val_loss: 0.0038 - val_bit_err: 0.0051
Epoch 57/100
250/250 - 48s - loss: 0.0035 - bit_err: 0.0047 - val_loss: 0.0035 - val_bit_err: 0.0048
Epoch 58/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0046 - val_loss: 0.0040 - val_bit_err: 0.0051
Epoch 59/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0046 - val_loss: 0.0029 - val_bit_err: 0.0039
Epoch 60/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0046 - val_loss: 0.0032 - val_bit_err: 0.0038
Epoch 61/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0045 - val_loss: 0.0029 - val_bit_err: 0.0038
Epoch 62/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0046 - val_loss: 0.0029 - val_bit_err: 0.0039
Epoch 63/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0046 - val_loss: 0.0024 - val_bit_err:

0.0032
Epoch 64/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0045 - val_loss: 0.0038 - val_bit_err: 0.0049
Epoch 65/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0045 - val_loss: 0.0032 - val_bit_err: 0.0044
Epoch 66/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0045 - val_loss: 0.0040 - val_bit_err: 0.0051
Epoch 67/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0046 - val_loss: 0.0037 - val_bit_err: 0.0050
Epoch 68/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0045 - val_loss: 0.0045 - val_bit_err: 0.0062
Epoch 69/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0029 - val_bit_err: 0.0036
Epoch 70/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0034 - val_bit_err: 0.0046
Epoch 71/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0045 - val_loss: 0.0030 - val_bit_err: 0.0039
Epoch 72/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0045 - val_loss: 0.0040 - val_bit_err: 0.0054
Epoch 73/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0045 - val_loss: 0.0040 - val_bit_err: 0.0052
Epoch 74/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0045 - val_loss: 0.0023 - val_bit_err: 0.0030
Epoch 75/100
250/250 - 48s - loss: 0.0034 - bit_err: 0.0046 - val_loss: 0.0027 - val_bit_err: 0.0034
Epoch 76/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0027 - val_bit_err: 0.0038
Epoch 77/100
250/250 - 48s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0045 - val_bit_err: 0.0059
Epoch 78/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0045 - val_loss: 0.0036 - val_bit_err: 0.0046
Epoch 79/100
250/250 - 48s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0040 - val_bit_err:

0.0052
Epoch 80/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0045 - val_loss: 0.0034 - val_bit_err:
0.0046
Epoch 81/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0028 - val_bit_err:
0.0036
Epoch 82/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0037 - val_bit_err:
0.0048
Epoch 83/100
250/250 - 48s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0030 - val_bit_err:
0.0040
Epoch 84/100
250/250 - 70s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0031 - val_bit_err:
0.0043
Epoch 85/100
250/250 - 59s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0030 - val_bit_err:
0.0041
Epoch 86/100
250/250 - 49s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0042 - val_bit_err:
0.0056
Epoch 87/100
250/250 - 50s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0035 - val_bit_err:
0.0048
Epoch 88/100
250/250 - 50s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0022 - val_bit_err:
0.0030
Epoch 89/100
250/250 - 57s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0029 - val_bit_err:
0.0038
Epoch 90/100
250/250 - 50s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0026 - val_bit_err:
0.0033
Epoch 91/100
250/250 - 50s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0043 - val_bit_err:
0.0056
Epoch 92/100
250/250 - 50s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0039 - val_bit_err:
0.0052
Epoch 93/100
250/250 - 49s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0031 - val_bit_err:
0.0043
Epoch 94/100
250/250 - 57s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0029 - val_bit_err:
0.0038
Epoch 95/100
250/250 - 78s - loss: 0.0033 - bit_err: 0.0044 - val_loss: 0.0034 - val_bit_err:

0.0046
 Epoch 96/100
 250/250 - 57s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0029 - val_bit_err:
 0.0039
 Epoch 97/100
 250/250 - 67s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0033 - val_bit_err:
 0.0046
 Epoch 98/100
 250/250 - 63s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0024 - val_bit_err:
 0.0031
 Epoch 99/100
 250/250 - 64s - loss: 0.0032 - bit_err: 0.0043 - val_loss: 0.0024 - val_bit_err:
 0.0037
 Epoch 100/100
 250/250 - 65s - loss: 0.0031 - bit_err: 0.0042 - val_loss: 0.0042 - val_bit_err:
 0.0058
 1/1 [=====] - 0s 2ms/step - loss: 0.0869 - bit_err:
 0.1025
 1/1 [=====] - 0s 2ms/step - loss: 0.0576 - bit_err:
 0.0690
 1/1 [=====] - 0s 2ms/step - loss: 0.0377 - bit_err:
 0.0452
 1/1 [=====] - 0s 2ms/step - loss: 0.0231 - bit_err:
 0.0281
 1/1 [=====] - 0s 3ms/step - loss: 0.0146 - bit_err:
 0.0179
 1/1 [=====] - 0s 2ms/step - loss: 0.0099 - bit_err:
 0.0124
 1/1 [=====] - 0s 1ms/step - loss: 0.0063 - bit_err:
 0.0083
 1/1 [=====] - 0s 1ms/step - loss: 0.0039 - bit_err:
 0.0052
 1/1 [=====] - 0s 2ms/step - loss: 0.0028 - bit_err:
 0.0037
 1/1 [=====] - 0s 3ms/step - loss: 0.0019 - bit_err:
 0.0027
 1/1 [=====] - 0s 3ms/step - loss: 0.0014 - bit_err:
 0.0020
 1/1 [=====] - 0s 2ms/step - loss: 0.0013 - bit_err:
 0.0018
 1/1 [=====] - 0s 2ms/step - loss: 0.0012 - bit_err:
 0.0015





CP = 16, P = 8, activation = sigmoid, lr = 0.001

```
[18]: run_all(16, 8, "sigmoid", 0.001)
```

Epoch 1/100

250/250 - 49s - loss: 0.2505 - bit_err: 0.4994 - val_loss: 0.2499 - val_bit_err: 0.4891

Epoch 2/100

250/250 - 49s - loss: 0.2382 - bit_err: 0.4248 - val_loss: 0.2168 - val_bit_err: 0.3347

Epoch 3/100

250/250 - 46s - loss: 0.1859 - bit_err: 0.2532 - val_loss: 0.1527 - val_bit_err: 0.1764

Epoch 4/100

250/250 - 52s - loss: 0.1208 - bit_err: 0.1187 - val_loss: 0.0941 - val_bit_err: 0.0798

Epoch 5/100

250/250 - 47s - loss: 0.0770 - bit_err: 0.0665 - val_loss: 0.0661 - val_bit_err: 0.0609

Epoch 6/100

250/250 - 58s - loss: 0.0542 - bit_err: 0.0494 - val_loss: 0.0483 - val_bit_err: 0.0472

Epoch 7/100

250/250 - 60s - loss: 0.0413 - bit_err: 0.0394 - val_loss: 0.0378 - val_bit_err:

0.0361
Epoch 8/100
250/250 - 61s - loss: 0.0324 - bit_err: 0.0312 - val_loss: 0.0296 - val_bit_err: 0.0292
Epoch 9/100
250/250 - 56s - loss: 0.0267 - bit_err: 0.0264 - val_loss: 0.0245 - val_bit_err: 0.0245
Epoch 10/100
250/250 - 58s - loss: 0.0226 - bit_err: 0.0229 - val_loss: 0.0215 - val_bit_err: 0.0224
Epoch 11/100
250/250 - 64s - loss: 0.0196 - bit_err: 0.0204 - val_loss: 0.0174 - val_bit_err: 0.0180
Epoch 12/100
250/250 - 67s - loss: 0.0176 - bit_err: 0.0190 - val_loss: 0.0167 - val_bit_err: 0.0182
Epoch 13/100
250/250 - 61s - loss: 0.0160 - bit_err: 0.0177 - val_loss: 0.0156 - val_bit_err: 0.0173
Epoch 14/100
250/250 - 64s - loss: 0.0146 - bit_err: 0.0167 - val_loss: 0.0133 - val_bit_err: 0.0141
Epoch 15/100
250/250 - 60s - loss: 0.0136 - bit_err: 0.0158 - val_loss: 0.0149 - val_bit_err: 0.0183
Epoch 16/100
250/250 - 70s - loss: 0.0130 - bit_err: 0.0154 - val_loss: 0.0103 - val_bit_err: 0.0115
Epoch 17/100
250/250 - 70s - loss: 0.0123 - bit_err: 0.0148 - val_loss: 0.0127 - val_bit_err: 0.0156
Epoch 18/100
250/250 - 65s - loss: 0.0117 - bit_err: 0.0142 - val_loss: 0.0118 - val_bit_err: 0.0138
Epoch 19/100
250/250 - 50s - loss: 0.0114 - bit_err: 0.0141 - val_loss: 0.0118 - val_bit_err: 0.0144
Epoch 20/100
250/250 - 60s - loss: 0.0110 - bit_err: 0.0138 - val_loss: 0.0116 - val_bit_err: 0.0146
Epoch 21/100
250/250 - 72s - loss: 0.0108 - bit_err: 0.0137 - val_loss: 0.0108 - val_bit_err: 0.0139
Epoch 22/100
250/250 - 68s - loss: 0.0104 - bit_err: 0.0133 - val_loss: 0.0104 - val_bit_err: 0.0139
Epoch 23/100
250/250 - 67s - loss: 0.0102 - bit_err: 0.0131 - val_loss: 0.0105 - val_bit_err:

0.0138
Epoch 24/100
250/250 - 61s - loss: 0.0099 - bit_err: 0.0128 - val_loss: 0.0104 - val_bit_err: 0.0142
Epoch 25/100
250/250 - 59s - loss: 0.0097 - bit_err: 0.0127 - val_loss: 0.0096 - val_bit_err: 0.0126
Epoch 26/100
250/250 - 52s - loss: 0.0097 - bit_err: 0.0126 - val_loss: 0.0079 - val_bit_err: 0.0097
Epoch 27/100
250/250 - 49s - loss: 0.0096 - bit_err: 0.0126 - val_loss: 0.0102 - val_bit_err: 0.0131
Epoch 28/100
250/250 - 57s - loss: 0.0094 - bit_err: 0.0125 - val_loss: 0.0080 - val_bit_err: 0.0109
Epoch 29/100
250/250 - 63s - loss: 0.0094 - bit_err: 0.0125 - val_loss: 0.0099 - val_bit_err: 0.0129
Epoch 30/100
250/250 - 49s - loss: 0.0091 - bit_err: 0.0121 - val_loss: 0.0091 - val_bit_err: 0.0116
Epoch 31/100
250/250 - 65s - loss: 0.0091 - bit_err: 0.0121 - val_loss: 0.0099 - val_bit_err: 0.0132
Epoch 32/100
250/250 - 64s - loss: 0.0091 - bit_err: 0.0121 - val_loss: 0.0088 - val_bit_err: 0.0124
Epoch 33/100
250/250 - 61s - loss: 0.0089 - bit_err: 0.0119 - val_loss: 0.0091 - val_bit_err: 0.0123
Epoch 34/100
250/250 - 62s - loss: 0.0089 - bit_err: 0.0119 - val_loss: 0.0094 - val_bit_err: 0.0123
Epoch 35/100
250/250 - 65s - loss: 0.0088 - bit_err: 0.0118 - val_loss: 0.0079 - val_bit_err: 0.0105
Epoch 36/100
250/250 - 68s - loss: 0.0088 - bit_err: 0.0118 - val_loss: 0.0092 - val_bit_err: 0.0127
Epoch 37/100
250/250 - 65s - loss: 0.0087 - bit_err: 0.0117 - val_loss: 0.0088 - val_bit_err: 0.0119
Epoch 38/100
250/250 - 73s - loss: 0.0086 - bit_err: 0.0116 - val_loss: 0.0086 - val_bit_err: 0.0116
Epoch 39/100
250/250 - 62s - loss: 0.0088 - bit_err: 0.0118 - val_loss: 0.0070 - val_bit_err:

0.0092
Epoch 40/100
250/250 - 70s - loss: 0.0086 - bit_err: 0.0116 - val_loss: 0.0092 - val_bit_err:
0.0121
Epoch 41/100
250/250 - 68s - loss: 0.0085 - bit_err: 0.0115 - val_loss: 0.0105 - val_bit_err:
0.0132
Epoch 42/100
250/250 - 56s - loss: 0.0085 - bit_err: 0.0115 - val_loss: 0.0092 - val_bit_err:
0.0125
Epoch 43/100
250/250 - 52s - loss: 0.0085 - bit_err: 0.0114 - val_loss: 0.0075 - val_bit_err:
0.0099
Epoch 44/100
250/250 - 54s - loss: 0.0084 - bit_err: 0.0114 - val_loss: 0.0079 - val_bit_err:
0.0100
Epoch 45/100
250/250 - 51s - loss: 0.0084 - bit_err: 0.0114 - val_loss: 0.0077 - val_bit_err:
0.0111
Epoch 46/100
250/250 - 73s - loss: 0.0084 - bit_err: 0.0113 - val_loss: 0.0097 - val_bit_err:
0.0130
Epoch 47/100
250/250 - 58s - loss: 0.0082 - bit_err: 0.0111 - val_loss: 0.0089 - val_bit_err:
0.0120
Epoch 48/100
250/250 - 53s - loss: 0.0084 - bit_err: 0.0113 - val_loss: 0.0089 - val_bit_err:
0.0118
Epoch 49/100
250/250 - 59s - loss: 0.0081 - bit_err: 0.0110 - val_loss: 0.0100 - val_bit_err:
0.0129
Epoch 50/100
250/250 - 50s - loss: 0.0084 - bit_err: 0.0113 - val_loss: 0.0081 - val_bit_err:
0.0112
Epoch 51/100
250/250 - 56s - loss: 0.0083 - bit_err: 0.0112 - val_loss: 0.0096 - val_bit_err:
0.0129
Epoch 52/100
250/250 - 56s - loss: 0.0082 - bit_err: 0.0111 - val_loss: 0.0081 - val_bit_err:
0.0111
Epoch 53/100
250/250 - 50s - loss: 0.0082 - bit_err: 0.0111 - val_loss: 0.0073 - val_bit_err:
0.0102
Epoch 54/100
250/250 - 54s - loss: 0.0082 - bit_err: 0.0111 - val_loss: 0.0072 - val_bit_err:
0.0091
Epoch 55/100
250/250 - 52s - loss: 0.0081 - bit_err: 0.0110 - val_loss: 0.0070 - val_bit_err:

0.0092
 Epoch 56/100
 250/250 - 50s - loss: 0.0082 - bit_err: 0.0110 - val_loss: 0.0096 - val_bit_err:
 0.0128
 Epoch 57/100
 250/250 - 49s - loss: 0.0081 - bit_err: 0.0110 - val_loss: 0.0081 - val_bit_err:
 0.0110
 Epoch 58/100
 250/250 - 52s - loss: 0.0081 - bit_err: 0.0109 - val_loss: 0.0080 - val_bit_err:
 0.0107
 Epoch 59/100
 250/250 - 48s - loss: 0.0080 - bit_err: 0.0108 - val_loss: 0.0071 - val_bit_err:
 0.0095
 Epoch 60/100
 250/250 - 48s - loss: 0.0081 - bit_err: 0.0109 - val_loss: 0.0098 - val_bit_err:
 0.0132
 Epoch 61/100
 250/250 - 48s - loss: 0.0080 - bit_err: 0.0108 - val_loss: 0.0079 - val_bit_err:
 0.0105
 Epoch 62/100
 250/250 - 48s - loss: 0.0080 - bit_err: 0.0108 - val_loss: 0.0071 - val_bit_err:
 0.0097
 Epoch 63/100
 250/250 - 48s - loss: 0.0080 - bit_err: 0.0108 - val_loss: 0.0086 - val_bit_err:
 0.0116
 Epoch 64/100
 250/250 - 48s - loss: 0.0078 - bit_err: 0.0106 - val_loss: 0.0072 - val_bit_err:
 0.0094
 Epoch 65/100
 250/250 - 48s - loss: 0.0080 - bit_err: 0.0107 - val_loss: 0.0089 - val_bit_err:
 0.0123
 Epoch 66/100
 250/250 - 48s - loss: 0.0078 - bit_err: 0.0106 - val_loss: 0.0081 - val_bit_err:
 0.0109
 Epoch 67/100
 250/250 - 48s - loss: 0.0079 - bit_err: 0.0107 - val_loss: 0.0072 - val_bit_err:
 0.0095
 Epoch 68/100
 250/250 - 48s - loss: 0.0079 - bit_err: 0.0107 - val_loss: 0.0073 - val_bit_err:
 0.0101
 Epoch 69/100
 250/250 - 47s - loss: 0.0078 - bit_err: 0.0104 - val_loss: 0.0076 - val_bit_err:
 0.0102
 Epoch 70/100
 250/250 - 48s - loss: 0.0080 - bit_err: 0.0107 - val_loss: 0.0089 - val_bit_err:
 0.0121
 Epoch 71/100
 250/250 - 49s - loss: 0.0078 - bit_err: 0.0104 - val_loss: 0.0103 - val_bit_err:

0.0132
Epoch 72/100
250/250 - 48s - loss: 0.0078 - bit_err: 0.0105 - val_loss: 0.0076 - val_bit_err:
0.0102
Epoch 73/100
250/250 - 48s - loss: 0.0079 - bit_err: 0.0106 - val_loss: 0.0089 - val_bit_err:
0.0115
Epoch 74/100
250/250 - 48s - loss: 0.0078 - bit_err: 0.0105 - val_loss: 0.0085 - val_bit_err:
0.0112
Epoch 75/100
250/250 - 48s - loss: 0.0077 - bit_err: 0.0104 - val_loss: 0.0084 - val_bit_err:
0.0116
Epoch 76/100
250/250 - 48s - loss: 0.0079 - bit_err: 0.0106 - val_loss: 0.0086 - val_bit_err:
0.0120
Epoch 77/100
250/250 - 48s - loss: 0.0077 - bit_err: 0.0103 - val_loss: 0.0096 - val_bit_err:
0.0128
Epoch 78/100
250/250 - 48s - loss: 0.0078 - bit_err: 0.0105 - val_loss: 0.0078 - val_bit_err:
0.0105
Epoch 79/100
250/250 - 48s - loss: 0.0076 - bit_err: 0.0103 - val_loss: 0.0068 - val_bit_err:
0.0095
Epoch 80/100
250/250 - 48s - loss: 0.0078 - bit_err: 0.0105 - val_loss: 0.0078 - val_bit_err:
0.0105
Epoch 81/100
250/250 - 48s - loss: 0.0077 - bit_err: 0.0104 - val_loss: 0.0068 - val_bit_err:
0.0089
Epoch 82/100
250/250 - 48s - loss: 0.0078 - bit_err: 0.0106 - val_loss: 0.0078 - val_bit_err:
0.0103
Epoch 83/100
250/250 - 48s - loss: 0.0076 - bit_err: 0.0103 - val_loss: 0.0074 - val_bit_err:
0.0094
Epoch 84/100
250/250 - 48s - loss: 0.0077 - bit_err: 0.0104 - val_loss: 0.0060 - val_bit_err:
0.0075
Epoch 85/100
250/250 - 48s - loss: 0.0076 - bit_err: 0.0102 - val_loss: 0.0079 - val_bit_err:
0.0111
Epoch 86/100
250/250 - 48s - loss: 0.0076 - bit_err: 0.0103 - val_loss: 0.0087 - val_bit_err:
0.0117
Epoch 87/100
250/250 - 48s - loss: 0.0075 - bit_err: 0.0101 - val_loss: 0.0081 - val_bit_err:

```

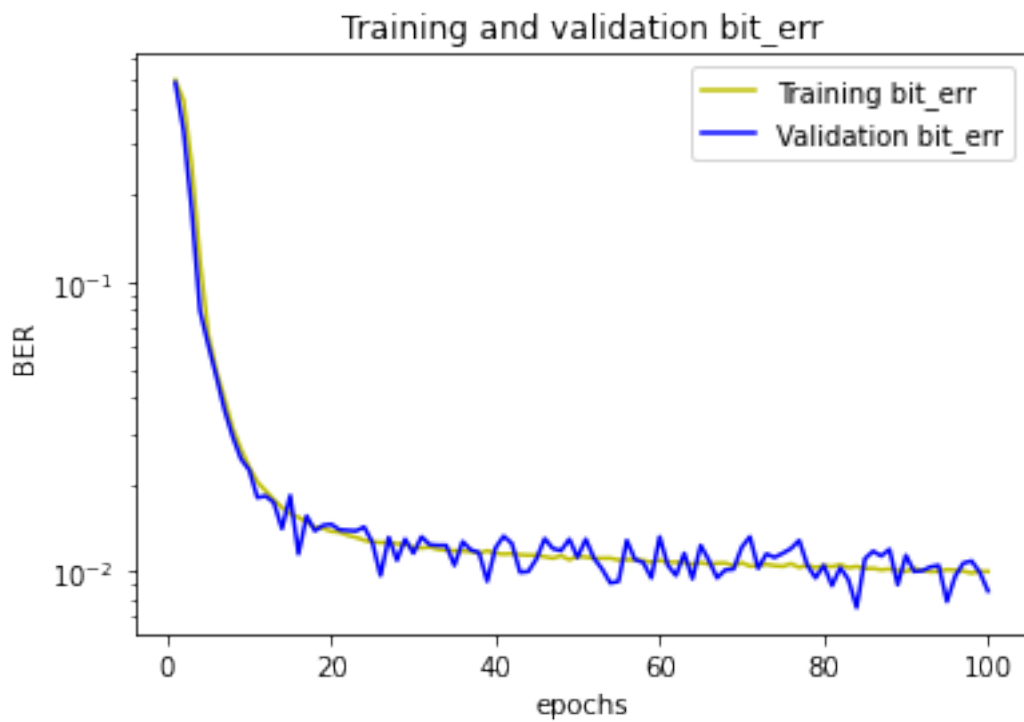
0.0113
Epoch 88/100
250/250 - 48s - loss: 0.0076 - bit_err: 0.0102 - val_loss: 0.0091 - val_bit_err:
0.0119
Epoch 89/100
250/250 - 48s - loss: 0.0075 - bit_err: 0.0101 - val_loss: 0.0068 - val_bit_err:
0.0090
Epoch 90/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0085 - val_bit_err:
0.0114
Epoch 91/100
250/250 - 48s - loss: 0.0076 - bit_err: 0.0103 - val_loss: 0.0076 - val_bit_err:
0.0100
Epoch 92/100
250/250 - 48s - loss: 0.0075 - bit_err: 0.0101 - val_loss: 0.0070 - val_bit_err:
0.0101
Epoch 93/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0077 - val_bit_err:
0.0104
Epoch 94/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0079 - val_bit_err:
0.0105
Epoch 95/100
250/250 - 48s - loss: 0.0075 - bit_err: 0.0102 - val_loss: 0.0058 - val_bit_err:
0.0079
Epoch 96/100
250/250 - 48s - loss: 0.0075 - bit_err: 0.0101 - val_loss: 0.0073 - val_bit_err:
0.0096
Epoch 97/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0075 - val_bit_err:
0.0107
Epoch 98/100
250/250 - 48s - loss: 0.0073 - bit_err: 0.0099 - val_loss: 0.0081 - val_bit_err:
0.0109
Epoch 99/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0072 - val_bit_err:
0.0099
Epoch 100/100
250/250 - 48s - loss: 0.0074 - bit_err: 0.0100 - val_loss: 0.0060 - val_bit_err:
0.0086
1/1 [=====] - 0s 2ms/step - loss: 0.1192 - bit_err:
0.1419
1/1 [=====] - 0s 2ms/step - loss: 0.0842 - bit_err:
0.1023
1/1 [=====] - 0s 1ms/step - loss: 0.0589 - bit_err:
0.0718
1/1 [=====] - 0s 2ms/step - loss: 0.0374 - bit_err:
0.0463

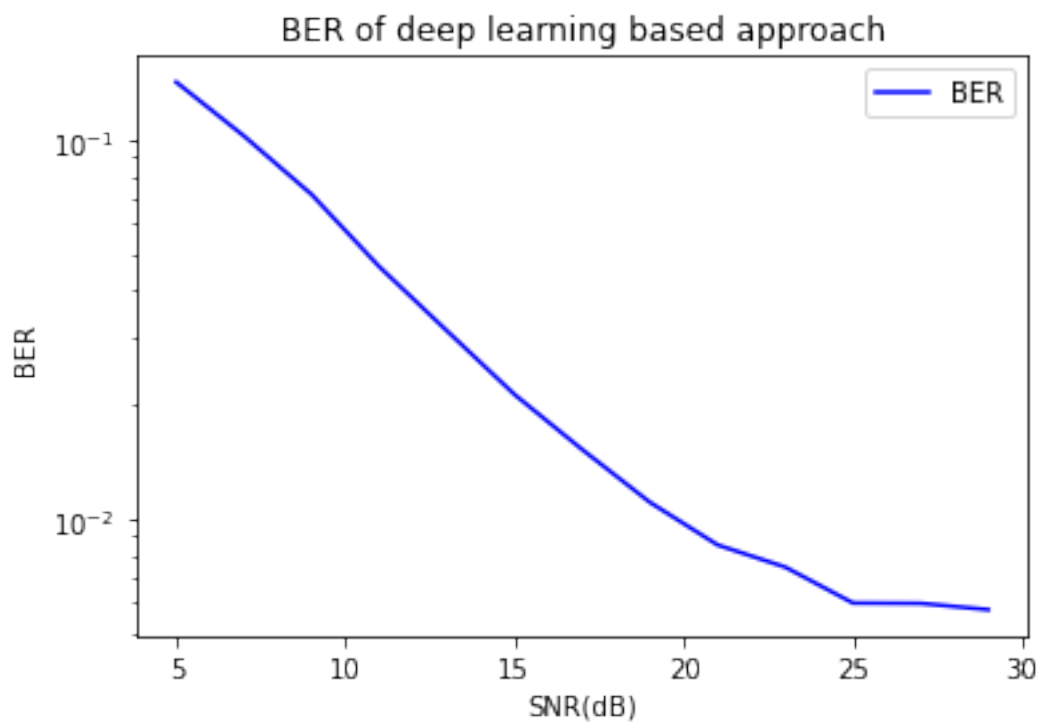
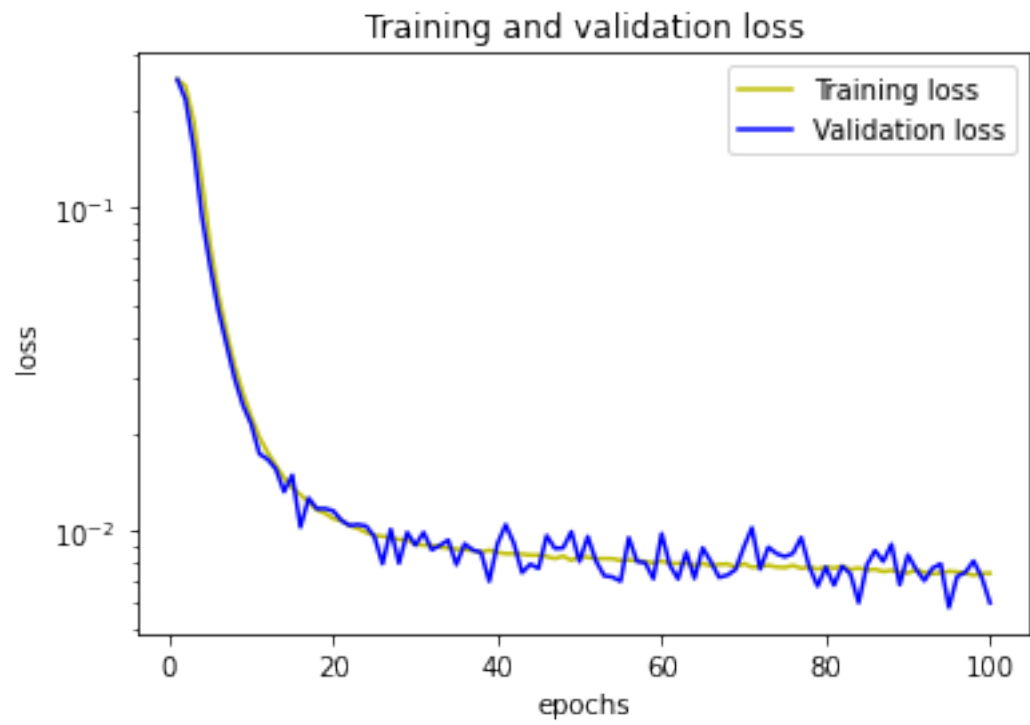
```

```

1/1 [=====] - 0s 1ms/step - loss: 0.0250 - bit_err:
0.0314
1/1 [=====] - 0s 2ms/step - loss: 0.0166 - bit_err:
0.0213
1/1 [=====] - 0s 2ms/step - loss: 0.0118 - bit_err:
0.0152
1/1 [=====] - 0s 2ms/step - loss: 0.0083 - bit_err:
0.0111
1/1 [=====] - 0s 1ms/step - loss: 0.0063 - bit_err:
0.0085
1/1 [=====] - 0s 2ms/step - loss: 0.0057 - bit_err:
0.0075
1/1 [=====] - 0s 2ms/step - loss: 0.0044 - bit_err:
0.0060
1/1 [=====] - 0s 3ms/step - loss: 0.0044 - bit_err:
0.0060
1/1 [=====] - 0s 1ms/step - loss: 0.0042 - bit_err:
0.0058

```





1.5

- P
 - P
 - P DNN
- CP
 -
 - CP CP DNN
- - 0.001 0.004 15
- - relu sigmoid