

Mount drive to allow for large files to be read

In [2]:

```
from google.colab import drive
drive.mount('/content/drive')
```

Mounted at /content/drive

Import required libraries for entire notebook

In [3]:

```
import pandas as pd
import numpy as np
import math
import tensorflow
import matplotlib.pyplot as plt
import tensorflow.keras

from tensorflow.keras.models import Sequential, Model
from tensorflow.keras.layers import Dense, Input, concatenate, Dropout, Conv2D, LSTM, Bidirectional, Flatten, Conv1D, GlobalMaxPooling1D, MaxPooling1D, Activation, BatchNormalization, MaxPooling2D, Flatten
from tensorflow.keras import initializers
from tensorflow.keras.regularizers import l1
from tensorflow.keras.optimizers import Adam

from sklearn import preprocessing
from sklearn.model_selection import train_test_split
from sklearn.utils import shuffle
from sklearn import decomposition

from sklearn.metrics import mean_absolute_error, mean_squared_error
```

Set random seed for reproducibility

In [4]:

```
tensorflow.random.set_seed(0)
np.random.seed(0)
```

Load and format data

The data is read in and split into sets depending on the number of antenna the data was generated from. This is then flattened and pre processed ready for any required dimensionality reduction.

In [5]:

```
def load_data(phase, magnitude, output_data, antenna_num):

    magnitude_data = []
    phase_data = []
    num_signals = int(magnitude.shape[0]/100)

    for i in range(num_signals):
        magnitude_data.append(magnitude[i*99:i*99+100, 0:antenna_num*antenna_num].flatten())
        phase_data.append(phase[i*99:i*99+100, 0:antenna_num*antenna_num].flatten())

    magnitude_data = np.asarray(magnitude_data).astype(np.float32)
    magnitude_data = preprocessing.MinMaxScaler().fit_transform(magnitude_data)
    phase_data = np.asarray(phase_data)
    phase_data = preprocessing.MinMaxScaler().fit_transform(phase_data)
    output_data = np.asarray(output_data).astype(np.float32)

    return [phase_data, magnitude_data, output_data]
```

In [6]:

```
def load_data_cnn(phase, magnitude, output_data, antenna_num):

    magnitude_data = []
    phase_data = []
    num_signals = int(magnitude.shape[0]/100)

    for i in range(num_signals):
        magnitude_data.append(magnitude[i*99:i*99+100, 0:antenna_num*antenna_num])
        phase_data.append(phase[i*99:i*99+100, 0:antenna_num*antenna_num])
        magnitude_data[i] = np.asarray(magnitude_data[i]).astype(np.float32)
        magnitude_data[i] = preprocessing.MinMaxScaler().fit_transform(magnitude_data[i])
        phase_data[i] = np.asarray(phase_data[i]).astype(np.float32)
        phase_data[i] = preprocessing.MinMaxScaler().fit_transform(phase_data[i])

    magnitude_data = np.asarray(magnitude_data).astype(np.float32)
    phase_data = np.asarray(phase_data).astype(np.float32)
    output_data = np.asarray(output_data).astype(np.float32)

    return [phase_data, magnitude_data, output_data]
```

Perform dimensionality reduction

Dimensionality reduction may be required depending on the size of the data before learning can be performed. The method below reduces the set to be 10 times smaller through principle component analysis.

In [7]:

```
def perform_dimensionality_reduction(phase_data, magnitude_data):

    n = int(phase_data.shape[1]/10)
    pca = decomposition.PCA(n_components=n)
    pca.fit(magnitude_data)
    magnitude_data = pca.transform(magnitude_data)
    pca.fit(phase_data)
    phase_data = pca.transform(phase_data)

    return [phase_data, magnitude_data]
```

Split into test and train

The data must be shuffled so that a balanced set of data is provided to both the test and train sets. Then data set must be split into test and train sets with the specific split specified.

In [8]:

```
def split_test_train(phase_data, magnitude_data, output_data, split):

    magnitude_data, phase_data, output_data = shuffle(magnitude_data, phase_data, output_data, random_state=0)
    x_train_magnitude, x_test_magnitude, x_train_phase, x_test_phase, y_train, y_test = train_test_split(magnitude_data, phase_data, output_data, test_size=split, random_state=0)

    return [x_train_magnitude, x_test_magnitude, x_train_phase, x_test_phase, y_train, y_test]
```

Create MLP

Parameterised creation of the multi-layer perceptron. Allows for different input shapes, specification of number of layers and number of neurons per layer, whether to complete the regression in this model or to leave it open for combination and allows for the specification of activation function.

In [9]:

```
def create_mlp(input_shape, layers, regress, activation_f):

    inputA = Input(shape=input_shape)

    for (i, f) in enumerate(layers):
        if i == 0:
            x = Dense(f, activation=activation_f)(inputA)
        else:
            x = Dense(f, activation=activation_f)(x)
            x = Dropout(0.3)(x)

    if regress:
        x = Dense(2, activation="linear")(x)

    return Model(inputs=inputA, outputs=x)
```

Create 1-D CNN

Parameterised creation of the one dimensional convolutional neural network. Allows for different input shapes, specification of number of layers and number of neurons per layer, whether to complete the regression in this model or to leave it open for combination and allows for the specification of activation function.

In [10]:

```
def create_1d_cnn(input_shape, regression, filters, layers, activation_f):

    inputA = Input(shape=input_shape)
    init_he_u = initializers.he_uniform(seed=None)
    Dim = 1

    for (i, f) in enumerate(filters):
        if i == 0:
            x = Conv1D(filters=f, kernel_size=3, activation=activation_f)(inputA)
            # x = BatchNormalization(axis=Dim)(x)
        else:
            x = Conv1D(filters=f, kernel_size=3, activation=activation_f)(x)
            # x = BatchNormalization(axis=Dim)(x)

    x = Dropout(0.5)(x)
    x = MaxPooling1D(pool_size=2)(x)
    x = Flatten()(x)

    for (i, f) in enumerate(layers):
        x = Dense(f, activation=activation_f)(x)
        # x = Dropout(0.3)(x)

    if regression:
        x = Dense(2, activation="linear")(x)

    x = Model(inputs=inputA, outputs=x)

    return x
```

Create 2-D CNN

Parameterised creation of the two dimensional convolutional neural network. Allows for different input shapes, specification of number of layers and number of neurons per layer, whether to complete the regression in this model or to leave it open for combination and allows for the specification of activation function.

In [11]:

```
def create_2d_cnn(height, width, depth, filters, regress, activation_f):  
  
    inputShape = (height, width, depth)  
    Dim = -1  
    # define the model input  
    inputs = Input(shape=inputShape)  
    # loop over the number of filters  
    for (i, f) in enumerate(filters):  
        if i == 0:  
            x = inputs  
            x = Conv2D(f, (3, 3), padding="same")(x)  
            x = Activation(activation_f)(x)  
            x = Dropout(0.25)(x)  
            x = BatchNormalization(axis=Dim)(x)  
            x = MaxPooling2D(pool_size=(1, 1))(x)  
  
        x = Flatten()(x)  
        x = Dense(16)(x)  
        x = Activation(activation_f)(x)  
        x = BatchNormalization(axis=Dim)(x)  
        x = Dropout(0.25)(x)  
        x = Dense(4)(x)  
        x = Activation(activation_f)(x)  
    if regress:  
        x = Dense(2, activation="linear")(x)  
    model = Model(inputs, x)  
  
    return model
```

Create LSTM - UNUSED

This method did not produce desirable results so has not been considered in the evaluation of the results.

In [12]:

```
def create_LSTM(input_shape, lstm_layers, layers, regression, activation_f):

    inputA = Input(shape=input_shape)
    init_he_u = initializers.he_uniform(seed=None)

    for (i, f) in enumerate(lstm_layers):
        if i == 0:
            x = Bidirectional(LSTM(f, activation=activation_f, return_sequences=True))(input
A)
        else:
            x = Bidirectional(LSTM(f, activation=activation_f))(x)
    x = Dropout(0.5)(x)
    x = Flatten()(x)

    for (i, f) in enumerate(layers):
        x = Dense(f, activation=activation_f)(x)
        x = Dropout(0.3)(x)

    if regression:
        x = Dense(2, activation="linear")(x)

    return Model(inputs=inputA, outputs=x)
```

Combine models

Take 2 artificial neural networks and combine them. This combination then flows into fully connected layers and the regression is completed with linear activation function

In [13]:

```
def combine_models(phase, magnitude, layers):

    combined = concatenate([magnitude.output, phase.output])

    for (i, f) in enumerate(layers):
        if i == 0:
            x = Dense(f, activation="relu")(combined)
        else:
            x = Dense(f, activation="relu")(x)
        # x = Dropout(0.3)(x)

    x = Dense(2, activation="linear")(x)

    return Model(inputs=[magnitude.input, phase.input], outputs=x)
```

Display graphs

Displays the graphs of Mean square error and mean absolute error to demonstrate the learning process across epochs.

In [14]:

```
def display_graphs(history):

    plt.plot(history.history['mse'])
    plt.plot(history.history['val_mse'])
    plt.title('Model accuracy mse')
    plt.ylabel('Accuracy')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Test'], loc='upper left')
    plt.show()

    plt.plot(history.history['mae'])
    plt.plot(history.history['val_mae'])
    plt.title('Model accuracy mae')
    plt.ylabel('Accuracy')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Test'], loc='upper left')
    plt.show()
```

Calculate MUSIC metrics

Calculate the mean square error and mean absolute error of the original MUSIC algorithm's direction of arrival estimations for comparison with the best model achieved.

In [15]:

```
def MUSIC_metrics(output_data):

    cleaned_data = []
    nan_index = []

    for i in range(len(output_data)):

        if math.isnan(output_data[i][3]) == False:
            cleaned_data.append(output_data[i])
        else:
            nan_index.append(i)

    cleaned_data = np.asarray(cleaned_data).astype(np.float32)
    prediction = cleaned_data[:,2:4]
    actual = cleaned_data[:,0:2]

    return [mean_absolute_error(actual, prediction), mean_squared_error(actual, prediction), nan_index]
```

Test the approaches

The approaches above will be tested as follows:

- Perform each of the major approaches (MLP, 1D-CNN, 2D-CNN) on magnitude and phase and the combine them into a regression
- Perform each of the major approaches separately against phase and magnitude

This will be performed against the data from the 2-by-2 antenna array, this data again with PCA performed on it and on data from the 8-by-8 antenna array with PCA performed on it.

2-by-2 antenna array

In []:

```
antenna_num = 2

magnitude = pd.read_csv('/content/drive/MyDrive/train_magnitude.csv', header=None).to_numpy()
output_data = pd.read_csv('/content/drive/MyDrive/train_outputs.csv', header=None).to_numpy()
phase = pd.read_csv('/content/drive/MyDrive/train_phase.csv', header=None).to_numpy()

data = load_data(phase, magnitude, output_data, antenna_num)
phase_data = data[0]
magnitude_data = data[1]
output_data = data[2]

output_data

data_split = split_test_train(phase_data, magnitude_data, output_data, 0.4)
x_train_magnitude = data_split[0]
x_test_magnitude = data_split[1]
x_train_phase = data_split[2]
x_test_phase = data_split[3]
y_train = data_split[4][:,0:2]
y_test = data_split[5][:,0:2]

lr = 0.001
epochs = 100
opt = Adam(learning_rate=lr)
```


In []:

```
print("Combined phase and magnitude MLP")

layers = (400, 200)
shape = (400,)
epochs = 100
magnitude = create_mlp(shape, layers, False, "relu")
phase = create_mlp(shape, layers, False, "relu")

model = combine_models(phase, magnitude, (100,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x=[x_train_magnitude, x_train_phase], y=y_train,
    validation_data=([x_test_magnitude, x_test_phase], y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Combined phase and magnitude MLP

Epoch 1/100

1099/1099 - 6s - loss: 1160.7988 - mse: 1160.7988 - mae: 29.1174 - val_loss: 839.3276 - val_mse: 839.3276 - val_mae: 22.1394 - 6s/epoch - 5ms/step

Epoch 2/100

1099/1099 - 5s - loss: 850.7573 - mse: 850.7573 - mae: 22.3549 - val_loss: 862.6932 - val_mse: 862.6932 - val_mae: 23.2301 - 5s/epoch - 5ms/step

Epoch 3/100

1099/1099 - 5s - loss: 886.6873 - mse: 886.6873 - mae: 23.3135 - val_loss: 822.5658 - val_mse: 822.5658 - val_mae: 21.8518 - 5s/epoch - 5ms/step

Epoch 4/100

1099/1099 - 5s - loss: 899.4001 - mse: 899.4001 - mae: 23.1954 - val_loss: 824.9865 - val_mse: 824.9865 - val_mae: 21.7179 - 5s/epoch - 5ms/step

Epoch 5/100

1099/1099 - 6s - loss: 889.7295 - mse: 889.7295 - mae: 22.8137 - val_loss: 831.6069 - val_mse: 831.6069 - val_mae: 22.0846 - 6s/epoch - 5ms/step

Epoch 6/100

1099/1099 - 6s - loss: 882.4093 - mse: 882.4093 - mae: 22.6073 - val_loss: 830.0228 - val_mse: 830.0228 - val_mae: 21.9897 - 6s/epoch - 5ms/step

Epoch 7/100

1099/1099 - 6s - loss: 882.7578 - mse: 882.7578 - mae: 22.6185 - val_loss: 836.4202 - val_mse: 836.4202 - val_mae: 22.2946 - 6s/epoch - 6ms/step

Epoch 8/100

1099/1099 - 6s - loss: 880.7620 - mse: 880.7620 - mae: 22.4999 - val_loss: 832.5888 - val_mse: 832.5888 - val_mae: 22.1424 - 6s/epoch - 5ms/step

Epoch 9/100

1099/1099 - 7s - loss: 877.4773 - mse: 877.4773 - mae: 22.4463 - val_loss: 824.7299 - val_mse: 824.7299 - val_mae: 21.7054 - 7s/epoch - 6ms/step

Epoch 10/100

1099/1099 - 6s - loss: 879.0146 - mse: 879.0146 - mae: 22.4808 - val_loss: 820.3440 - val_mse: 820.3440 - val_mae: 21.4648 - 6s/epoch - 6ms/step

Epoch 11/100

1099/1099 - 7s - loss: 877.4171 - mse: 877.4171 - mae: 22.4215 - val_loss: 833.1630 - val_mse: 833.1630 - val_mae: 22.1613 - 7s/epoch - 7ms/step

Epoch 12/100

1099/1099 - 7s - loss: 879.0385 - mse: 879.0385 - mae: 22.4585 - val_loss: 828.8568 - val_mse: 828.8568 - val_mae: 21.9412 - 7s/epoch - 7ms/step

Epoch 13/100

1099/1099 - 6s - loss: 878.4192 - mse: 878.4192 - mae: 22.4000 - val_loss: 855.6198 - val_mse: 855.6198 - val_mae: 23.2440 - 6s/epoch - 6ms/step

Epoch 14/100

1099/1099 - 6s - loss: 879.1103 - mse: 879.1103 - mae: 22.4191 - val_loss: 864.3791 - val_mse: 864.3791 - val_mae: 23.5197 - 6s/epoch - 6ms/step

Epoch 15/100

1099/1099 - 6s - loss: 876.4810 - mse: 876.4810 - mae: 22.3373 - val_loss: 826.1522 - val_mse: 826.1522 - val_mae: 21.8016 - 6s/epoch - 6ms/step

Epoch 16/100

1099/1099 - 6s - loss: 875.8093 - mse: 875.8093 - mae: 22.3037 - val_loss: 866.4000 - val_mse: 866.4000 - val_mae: 23.5347 - 6s/epoch - 5ms/step

Epoch 17/100

1099/1099 - 6s - loss: 875.7653 - mse: 875.7653 - mae: 22.3045 - val_loss: 859.7999 - val_mse: 859.7999 - val_mae: 23.3320 - 6s/epoch - 5ms/step

Epoch 18/100

1099/1099 - 6s - loss: 875.1384 - mse: 875.1384 - mae: 22.2903 - val_loss: 854.0276 - val_mse: 854.0276 - val_mae: 23.0777 - 6s/epoch - 6ms/step

Epoch 19/100

1099/1099 - 7s - loss: 872.4057 - mse: 872.4057 - mae: 22.2192 - val_loss: 831.4733 - val_mse: 831.4733 - val_mae: 21.9210 - 7s/epoch - 6ms/step

Epoch 20/100

1099/1099 - 6s - loss: 871.0380 - mse: 871.0380 - mae: 22.1650 - val_loss: 819.5001 - val_mse: 819.5001 - val_mae: 21.4107 - 6s/epoch - 6ms/step

Epoch 21/100

1099/1099 - 6s - loss: 872.9109 - mse: 872.9109 - mae: 22.2108 - val_loss: 869.9047 - val_mse: 869.9047 - val_mae: 23.6510 - 6s/epoch - 6ms/step

Epoch 22/100

1099/1099 - 6s - loss: 871.2349 - mse: 871.2349 - mae: 22.1822 - val_loss: 843.9302 - val_mse: 843.9302 - val_mae: 22.5877 - 6s/epoch - 6ms/step

Epoch 23/100

1099/1099 - 7s - loss: 871.1306 - mse: 871.1306 - mae: 22.1468 - val_loss: 848.7200 - val_mse: 848.7200 - val_mae: 22.8482 - 7s/epoch - 7ms/step

Epoch 24/100

1099/1099 - 7s - loss: 870.4270 - mse: 870.4270 - mae: 22.1254 - val_loss: 870.5290 - val_mse: 870.5290 - val_mae: 23.6345 - 7s/epoch - 6ms/step

Epoch 25/100

1099/1099 - 6s - loss: 869.1323 - mse: 869.1323 - mae: 22.1169 - val_loss: 838.6544 - val_mse: 838.6544 - val_mae: 22.3321 - 6s/epoch - 6ms/step

Epoch 26/100

1099/1099 - 6s - loss: 869.9578 - mse: 869.9578 - mae: 22.1771 - val_loss: 844.3145 - val_mse: 844.3145 - val_mae: 22.6276 - 6s/epoch - 5ms/step

Epoch 27/100

1099/1099 - 6s - loss: 868.0432 - mse: 868.0432 - mae: 22.0504 - val_loss: 844.0268 - val_mse: 844.0268 - val_mae: 22.6148 - 6s/epoch - 6ms/step

Epoch 28/100

1099/1099 - 6s - loss: 869.2097 - mse: 869.2097 - mae: 22.1096 - val_loss: 847.3115 - val_mse: 847.3115 - val_mae: 22.6904 - 6s/epoch - 6ms/step

Epoch 29/100

1099/1099 - 6s - loss: 868.6246 - mse: 868.6246 - mae: 22.0933 - val_loss: 824.5530 - val_mse: 824.5530 - val_mae: 21.5711 - 6s/epoch - 6ms/step

Epoch 30/100

1099/1099 - 6s - loss: 866.3220 - mse: 866.3220 - mae: 22.0226 - val_loss: 873.5677 - val_mse: 873.5677 - val_mae: 23.7237 - 6s/epoch - 6ms/step

Epoch 31/100

1099/1099 - 6s - loss: 864.9031 - mse: 864.9031 - mae: 21.9878 - val_loss: 872.0814 - val_mse: 872.0814 - val_mae: 23.5719 - 6s/epoch - 6ms/step

Epoch 32/100

1099/1099 - 7s - loss: 862.2986 - mse: 862.2986 - mae: 21.9398 - val_loss: 932.2325 - val_mse: 932.2325 - val_mae: 25.4769 - 7s/epoch - 7ms/step

Epoch 33/100

1099/1099 - 6s - loss: 856.8076 - mse: 856.8076 - mae: 22.3601 - val_loss: 1003.2310 - val_mse: 1003.2310 - val_mae: 26.8228 - 6s/epoch - 6ms/step

Epoch 34/100

1099/1099 - 6s - loss: 845.2343 - mse: 845.2343 - mae: 21.9452 - val_loss: 921.0217 - val_mse: 921.0217 - val_mae: 24.9933 - 6s/epoch - 6ms/step

Epoch 35/100

1099/1099 - 6s - loss: 843.0671 - mse: 843.0671 - mae: 21.8988 - val_loss: 1180.0701 - val_mse: 1180.0701 - val_mae: 29.9771 - 6s/epoch - 6ms/step

Epoch 36/100

1099/1099 - 6s - loss: 837.4772 - mse: 837.4772 - mae: 21.7079 - val_loss: 990.1541 - val_mse: 990.1541 - val_mae: 26.3452 - 6s/epoch - 6ms/step

Epoch 37/100

1099/1099 - 6s - loss: 835.5450 - mse: 835.5450 - mae: 21.6329 - val_loss: 992.3663 - val_mse: 992.3663 - val_mae: 26.6696 - 6s/epoch - 6ms/step

Epoch 38/100

1099/1099 - 6s - loss: 836.1897 - mse: 836.1897 - mae: 21.7209 - val_loss: 896.5911 - val_mse: 896.5911 - val_mae: 24.2484 - 6s/epoch - 6ms/step

Epoch 39/100

1099/1099 - 7s - loss: 837.8904 - mse: 837.8904 - mae: 21.7402 - val_loss: 991.7977 - val_mse: 991.7977 - val_mae: 26.5844 - 7s/epoch - 7ms/step

Epoch 40/100

1099/1099 - 6s - loss: 835.1814 - mse: 835.1814 - mae: 21.6376 - val_loss: 950.8079 - val_mse: 950.8079 - val_mae: 25.6758 - 6s/epoch - 6ms/step

Epoch 41/100

1099/1099 - 6s - loss: 833.3247 - mse: 833.3247 - mae: 21.5855 - val_loss: 910.2947 - val_mse: 910.2947 - val_mae: 24.3208 - 6s/epoch - 6ms/step
Epoch 42/100
1099/1099 - 6s - loss: 834.6976 - mse: 834.6976 - mae: 21.6569 - val_loss: 1014.4595 - val_mse: 1014.4595 - val_mae: 27.0005 - 6s/epoch - 6ms/step
Epoch 43/100
1099/1099 - 6s - loss: 831.9370 - mse: 831.9370 - mae: 21.5855 - val_loss: 971.4543 - val_mse: 971.4543 - val_mae: 26.1990 - 6s/epoch - 6ms/step
Epoch 44/100
1099/1099 - 7s - loss: 834.3298 - mse: 834.3298 - mae: 21.6601 - val_loss: 1015.9818 - val_mse: 1015.9818 - val_mae: 27.2290 - 7s/epoch - 7ms/step
Epoch 45/100
1099/1099 - 6s - loss: 828.3297 - mse: 828.3297 - mae: 21.4770 - val_loss: 987.4369 - val_mse: 987.4369 - val_mae: 26.4562 - 6s/epoch - 5ms/step
Epoch 46/100
1099/1099 - 6s - loss: 832.3073 - mse: 832.3073 - mae: 21.5583 - val_loss: 954.5560 - val_mse: 954.5560 - val_mae: 25.9113 - 6s/epoch - 6ms/step
Epoch 47/100
1099/1099 - 6s - loss: 829.1141 - mse: 829.1141 - mae: 21.4831 - val_loss: 1007.4603 - val_mse: 1007.4603 - val_mae: 26.8880 - 6s/epoch - 6ms/step
Epoch 48/100
1099/1099 - 6s - loss: 827.4802 - mse: 827.4802 - mae: 21.4408 - val_loss: 1044.4388 - val_mse: 1044.4388 - val_mae: 27.6558 - 6s/epoch - 6ms/step
Epoch 49/100
1099/1099 - 6s - loss: 829.3449 - mse: 829.3449 - mae: 21.4961 - val_loss: 975.7231 - val_mse: 975.7231 - val_mae: 26.3347 - 6s/epoch - 6ms/step
Epoch 50/100
1099/1099 - 7s - loss: 829.1282 - mse: 829.1282 - mae: 21.4973 - val_loss: 887.6825 - val_mse: 887.6825 - val_mae: 23.8855 - 7s/epoch - 7ms/step
Epoch 51/100
1099/1099 - 6s - loss: 825.1048 - mse: 825.1048 - mae: 21.3619 - val_loss: 1000.1084 - val_mse: 1000.1084 - val_mae: 26.9502 - 6s/epoch - 6ms/step
Epoch 52/100
1099/1099 - 6s - loss: 827.0781 - mse: 827.0781 - mae: 21.4194 - val_loss: 892.9966 - val_mse: 892.9966 - val_mae: 24.1649 - 6s/epoch - 6ms/step
Epoch 53/100
1099/1099 - 6s - loss: 825.1522 - mse: 825.1522 - mae: 21.3374 - val_loss: 1018.4515 - val_mse: 1018.4515 - val_mae: 27.1628 - 6s/epoch - 6ms/step
Epoch 54/100
1099/1099 - 6s - loss: 828.1694 - mse: 828.1694 - mae: 21.4839 - val_loss: 887.5793 - val_mse: 887.5793 - val_mae: 23.7374 - 6s/epoch - 6ms/step
Epoch 55/100
1099/1099 - 6s - loss: 823.4644 - mse: 823.4644 - mae: 21.3255 - val_loss: 981.0608 - val_mse: 981.0608 - val_mae: 26.2095 - 6s/epoch - 6ms/step
Epoch 56/100
1099/1099 - 6s - loss: 825.6766 - mse: 825.6766 - mae: 21.4323 - val_loss: 910.5843 - val_mse: 910.5843 - val_mae: 24.0649 - 6s/epoch - 6ms/step
Epoch 57/100
1099/1099 - 6s - loss: 828.0320 - mse: 828.0320 - mae: 21.4993 - val_loss: 981.6595 - val_mse: 981.6595 - val_mae: 26.1670 - 6s/epoch - 6ms/step
Epoch 58/100
1099/1099 - 6s - loss: 825.9957 - mse: 825.9957 - mae: 21.4299 - val_loss: 887.8928 - val_mse: 887.8928 - val_mae: 23.9181 - 6s/epoch - 5ms/step
Epoch 59/100
1099/1099 - 6s - loss: 821.7504 - mse: 821.7504 - mae: 21.2495 - val_loss: 933.5782 - val_mse: 933.5782 - val_mae: 25.1809 - 6s/epoch - 6ms/step
Epoch 60/100
1099/1099 - 6s - loss: 825.7421 - mse: 825.7421 - mae: 21.4689 - val_loss: 920.7244 - val_mse: 920.7244 - val_mae: 24.6342 - 6s/epoch - 6ms/step
Epoch 61/100
1099/1099 - 6s - loss: 825.4214 - mse: 825.4214 - mae: 21.4020 - val_loss:

973.1340 - val_mse: 973.1340 - val_mae: 25.8471 - 6s/epoch - 6ms/step
Epoch 62/100
1099/1099 - 6s - loss: 823.8640 - mse: 823.8640 - mae: 21.3425 - val_loss:
994.8273 - val_mse: 994.8273 - val_mae: 26.8518 - 6s/epoch - 6ms/step
Epoch 63/100
1099/1099 - 6s - loss: 821.8875 - mse: 821.8875 - mae: 21.2884 - val_loss:
961.1295 - val_mse: 961.1295 - val_mae: 25.7012 - 6s/epoch - 6ms/step
Epoch 64/100
1099/1099 - 6s - loss: 822.3743 - mse: 822.3743 - mae: 21.3059 - val_loss:
963.3755 - val_mse: 963.3755 - val_mae: 25.9735 - 6s/epoch - 6ms/step
Epoch 65/100
1099/1099 - 6s - loss: 823.1197 - mse: 823.1197 - mae: 21.2894 - val_loss:
1076.0620 - val_mse: 1076.0620 - val_mae: 28.2659 - 6s/epoch - 6ms/step
Epoch 66/100
1099/1099 - 6s - loss: 823.2582 - mse: 823.2582 - mae: 21.3467 - val_loss:
924.6721 - val_mse: 924.6721 - val_mae: 25.2733 - 6s/epoch - 6ms/step
Epoch 67/100
1099/1099 - 7s - loss: 819.0307 - mse: 819.0307 - mae: 21.2006 - val_loss:
1038.4603 - val_mse: 1038.4603 - val_mae: 27.6934 - 7s/epoch - 7ms/step
Epoch 68/100
1099/1099 - 6s - loss: 821.0760 - mse: 821.0760 - mae: 21.2722 - val_loss:
957.9235 - val_mse: 957.9235 - val_mae: 25.8656 - 6s/epoch - 6ms/step
Epoch 69/100
1099/1099 - 6s - loss: 819.2399 - mse: 819.2399 - mae: 21.2049 - val_loss:
1012.6394 - val_mse: 1012.6394 - val_mae: 27.0028 - 6s/epoch - 6ms/step
Epoch 70/100
1099/1099 - 6s - loss: 821.4293 - mse: 821.4293 - mae: 21.3082 - val_loss:
953.3994 - val_mse: 953.3994 - val_mae: 25.9336 - 6s/epoch - 6ms/step
Epoch 71/100
1099/1099 - 6s - loss: 818.0891 - mse: 818.0891 - mae: 21.1422 - val_loss:
990.7744 - val_mse: 990.7744 - val_mae: 26.5428 - 6s/epoch - 5ms/step
Epoch 72/100
1099/1099 - 6s - loss: 819.9103 - mse: 819.9103 - mae: 21.2322 - val_loss:
970.6887 - val_mse: 970.6887 - val_mae: 26.1720 - 6s/epoch - 6ms/step
Epoch 73/100
1099/1099 - 6s - loss: 821.0626 - mse: 821.0626 - mae: 21.2708 - val_loss:
902.1854 - val_mse: 902.1854 - val_mae: 24.2350 - 6s/epoch - 6ms/step
Epoch 74/100
1099/1099 - 6s - loss: 820.0794 - mse: 820.0794 - mae: 21.2683 - val_loss:
1049.1769 - val_mse: 1049.1769 - val_mae: 27.9341 - 6s/epoch - 6ms/step
Epoch 75/100
1099/1099 - 6s - loss: 819.6113 - mse: 819.6113 - mae: 21.2348 - val_loss:
991.4899 - val_mse: 991.4899 - val_mae: 26.5289 - 6s/epoch - 6ms/step
Epoch 76/100
1099/1099 - 6s - loss: 821.8063 - mse: 821.8063 - mae: 21.3477 - val_loss:
947.4858 - val_mse: 947.4858 - val_mae: 25.4427 - 6s/epoch - 6ms/step
Epoch 77/100
1099/1099 - 6s - loss: 818.5608 - mse: 818.5608 - mae: 21.2030 - val_loss:
1007.5850 - val_mse: 1007.5850 - val_mae: 27.0520 - 6s/epoch - 6ms/step
Epoch 78/100
1099/1099 - 6s - loss: 821.1790 - mse: 821.1790 - mae: 21.2650 - val_loss:
991.5563 - val_mse: 991.5563 - val_mae: 26.6328 - 6s/epoch - 6ms/step
Epoch 79/100
1099/1099 - 6s - loss: 818.3260 - mse: 818.3260 - mae: 21.1611 - val_loss:
913.4271 - val_mse: 913.4271 - val_mae: 24.5380 - 6s/epoch - 6ms/step
Epoch 80/100
1099/1099 - 6s - loss: 820.8469 - mse: 820.8469 - mae: 21.2970 - val_loss:
934.7679 - val_mse: 934.7679 - val_mae: 25.3277 - 6s/epoch - 6ms/step
Epoch 81/100
1099/1099 - 6s - loss: 816.0352 - mse: 816.0352 - mae: 21.0942 - val_loss:
970.8801 - val_mse: 970.8801 - val_mae: 26.1254 - 6s/epoch - 6ms/step

Epoch 82/100

1099/1099 - 6s - loss: 816.1267 - mse: 816.1267 - mae: 21.1407 - val_loss:
1035.9791 - val_mse: 1035.9791 - val_mae: 27.5966 - 6s/epoch - 6ms/step

Epoch 83/100

1099/1099 - 6s - loss: 821.0897 - mse: 821.0897 - mae: 21.3090 - val_loss:
1070.9496 - val_mse: 1070.9496 - val_mae: 28.2598 - 6s/epoch - 6ms/step

Epoch 84/100

1099/1099 - 6s - loss: 817.3135 - mse: 817.3135 - mae: 21.1630 - val_loss:
949.0818 - val_mse: 949.0818 - val_mae: 25.7700 - 6s/epoch - 6ms/step

Epoch 85/100

1099/1099 - 6s - loss: 817.8994 - mse: 817.8994 - mae: 21.1881 - val_loss:
1013.4827 - val_mse: 1013.4827 - val_mae: 27.1379 - 6s/epoch - 6ms/step

Epoch 86/100

1099/1099 - 6s - loss: 817.3448 - mse: 817.3448 - mae: 21.1482 - val_loss:
988.7957 - val_mse: 988.7957 - val_mae: 26.5657 - 6s/epoch - 6ms/step

Epoch 87/100

1099/1099 - 6s - loss: 817.2839 - mse: 817.2839 - mae: 21.1503 - val_loss:
1009.3849 - val_mse: 1009.3849 - val_mae: 27.1494 - 6s/epoch - 6ms/step

Epoch 88/100

1099/1099 - 6s - loss: 815.7974 - mse: 815.7974 - mae: 21.0990 - val_loss:
1032.8468 - val_mse: 1032.8468 - val_mae: 27.3752 - 6s/epoch - 6ms/step

Epoch 89/100

1099/1099 - 7s - loss: 818.4869 - mse: 818.4869 - mae: 21.2144 - val_loss:
1086.7516 - val_mse: 1086.7516 - val_mae: 28.5238 - 7s/epoch - 7ms/step

Epoch 90/100

1099/1099 - 6s - loss: 818.3413 - mse: 818.3413 - mae: 21.1691 - val_loss:
1019.2678 - val_mse: 1019.2678 - val_mae: 27.2985 - 6s/epoch - 6ms/step

Epoch 91/100

1099/1099 - 6s - loss: 817.2847 - mse: 817.2847 - mae: 21.1618 - val_loss:
1105.4916 - val_mse: 1105.4916 - val_mae: 28.9366 - 6s/epoch - 6ms/step

Epoch 92/100

1099/1099 - 6s - loss: 861.6264 - mse: 861.6264 - mae: 22.2756 - val_loss:
939.6790 - val_mse: 939.6790 - val_mae: 25.6983 - 6s/epoch - 6ms/step

Epoch 93/100

1099/1099 - 6s - loss: 854.3825 - mse: 854.3825 - mae: 22.0392 - val_loss:
1060.2773 - val_mse: 1060.2773 - val_mae: 28.0078 - 6s/epoch - 6ms/step

Epoch 94/100

1099/1099 - 6s - loss: 853.1929 - mse: 853.1929 - mae: 22.0329 - val_loss:
955.7607 - val_mse: 955.7607 - val_mae: 25.8691 - 6s/epoch - 6ms/step

Epoch 95/100

1099/1099 - 6s - loss: 851.3802 - mse: 851.3802 - mae: 21.9998 - val_loss:
981.9319 - val_mse: 981.9319 - val_mae: 26.5908 - 6s/epoch - 6ms/step

Epoch 96/100

1099/1099 - 6s - loss: 847.2726 - mse: 847.2726 - mae: 21.8679 - val_loss:
1003.0464 - val_mse: 1003.0464 - val_mae: 27.0066 - 6s/epoch - 6ms/step

Epoch 97/100

1099/1099 - 6s - loss: 848.1429 - mse: 848.1429 - mae: 21.8826 - val_loss:
948.3785 - val_mse: 948.3785 - val_mae: 25.6810 - 6s/epoch - 6ms/step

Epoch 98/100

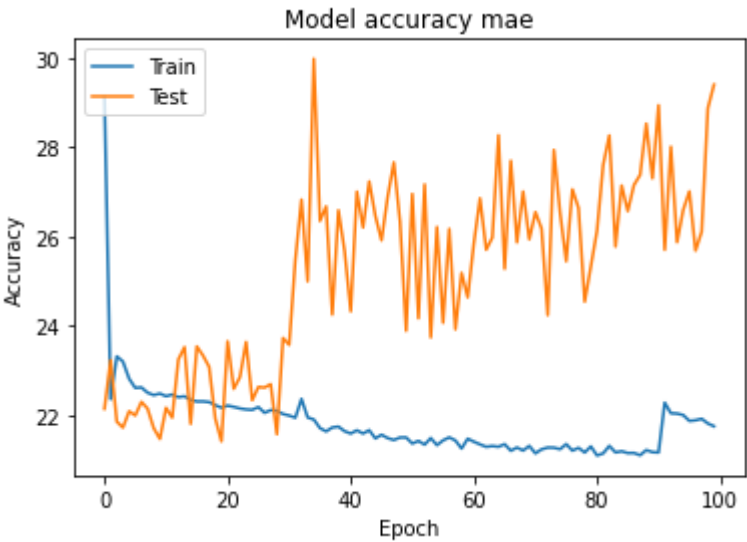
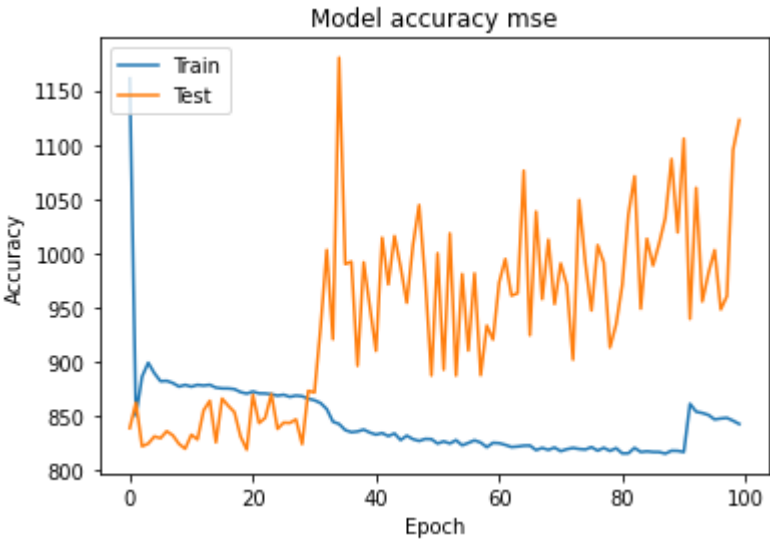
1099/1099 - 7s - loss: 848.6848 - mse: 848.6848 - mae: 21.9154 - val_loss:
960.7416 - val_mse: 960.7416 - val_mae: 26.1054 - 7s/epoch - 7ms/step

Epoch 99/100

1099/1099 - 6s - loss: 846.0694 - mse: 846.0694 - mae: 21.8110 - val_loss:
1095.2157 - val_mse: 1095.2157 - val_mae: 28.8653 - 6s/epoch - 6ms/step

Epoch 100/100

1099/1099 - 6s - loss: 843.0551 - mse: 843.0551 - mae: 21.7486 - val_loss:
1122.6912 - val_mse: 1122.6912 - val_mae: 29.3969 - 6s/epoch - 6ms/step



In []:

```
print("Combined phase and magnitude 1D CNN")

shape=(400,1)
filters=(64,64)
layers=(100,)
epochs = 25

phase = create_1d_cnn(shape, False, filters, layers, 'relu')
magnitude = create_1d_cnn(shape, False, filters, layers, 'relu')

model = combine_models(phase, magnitude, (100,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
x=[x_train_magnitude, x_train_phase], y=y_train,
  validation_data=(x_test_magnitude, x_test_phase), y_test),
  epochs=epochs, batch_size=32, verbose=2
)

display_graphs(history)
```


Combined phase and magnitude 1D CNN

Epoch 1/25

2197/2197 - 80s - loss: 1220.6002 - mse: 1220.6002 - mae: 30.2637 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 80s/epoch - 36ms/step

Epoch 2/25

2197/2197 - 79s - loss: 1157.1746 - mse: 1157.1746 - mae: 29.0005 - val_loss: 872.7557 - val_mse: 872.7557 - val_mae: 23.1333 - 79s/epoch - 36ms/step

Epoch 3/25

2197/2197 - 79s - loss: 892.3754 - mse: 892.3754 - mae: 23.4623 - val_loss: 841.6179 - val_mse: 841.6179 - val_mae: 22.3831 - 79s/epoch - 36ms/step

Epoch 4/25

2197/2197 - 80s - loss: 859.7294 - mse: 859.7294 - mae: 22.6779 - val_loss: 816.6395 - val_mse: 816.6395 - val_mae: 21.5457 - 80s/epoch - 37ms/step

Epoch 5/25

2197/2197 - 79s - loss: 847.0652 - mse: 847.0652 - mae: 22.3496 - val_loss: 817.9431 - val_mse: 817.9431 - val_mae: 21.5676 - 79s/epoch - 36ms/step

Epoch 6/25

2197/2197 - 79s - loss: 840.1111 - mse: 840.1111 - mae: 22.1464 - val_loss: 805.5706 - val_mse: 805.5706 - val_mae: 21.0332 - 79s/epoch - 36ms/step

Epoch 7/25

2197/2197 - 79s - loss: 837.1849 - mse: 837.1849 - mae: 22.0298 - val_loss: 803.6928 - val_mse: 803.6928 - val_mae: 20.9130 - 79s/epoch - 36ms/step

Epoch 8/25

2197/2197 - 79s - loss: 833.8599 - mse: 833.8599 - mae: 21.9441 - val_loss: 804.5002 - val_mse: 804.5002 - val_mae: 21.0440 - 79s/epoch - 36ms/step

Epoch 9/25

2197/2197 - 79s - loss: 831.5854 - mse: 831.5854 - mae: 21.8482 - val_loss: 799.5566 - val_mse: 799.5566 - val_mae: 20.7610 - 79s/epoch - 36ms/step

Epoch 10/25

2197/2197 - 79s - loss: 828.8486 - mse: 828.8486 - mae: 21.7598 - val_loss: 797.6318 - val_mse: 797.6318 - val_mae: 20.6770 - 79s/epoch - 36ms/step

Epoch 11/25

2197/2197 - 79s - loss: 826.9105 - mse: 826.9105 - mae: 21.7105 - val_loss: 800.8671 - val_mse: 800.8671 - val_mae: 20.8350 - 79s/epoch - 36ms/step

Epoch 12/25

2197/2197 - 79s - loss: 824.7219 - mse: 824.7219 - mae: 21.6550 - val_loss: 798.1375 - val_mse: 798.1375 - val_mae: 20.7393 - 79s/epoch - 36ms/step

Epoch 13/25

2197/2197 - 81s - loss: 824.5361 - mse: 824.5361 - mae: 21.6288 - val_loss: 798.0524 - val_mse: 798.0524 - val_mae: 20.7259 - 81s/epoch - 37ms/step

Epoch 14/25

2197/2197 - 80s - loss: 821.8154 - mse: 821.8154 - mae: 21.5439 - val_loss: 798.1330 - val_mse: 798.1330 - val_mae: 20.8334 - 80s/epoch - 36ms/step

Epoch 15/25

2197/2197 - 80s - loss: 819.6967 - mse: 819.6967 - mae: 21.4776 - val_loss: 791.4188 - val_mse: 791.4188 - val_mae: 20.3518 - 80s/epoch - 36ms/step

Epoch 16/25

2197/2197 - 79s - loss: 816.9409 - mse: 816.9409 - mae: 21.4119 - val_loss: 793.8566 - val_mse: 793.8566 - val_mae: 20.5989 - 79s/epoch - 36ms/step

Epoch 17/25

2197/2197 - 80s - loss: 815.9241 - mse: 815.9241 - mae: 21.3939 - val_loss: 793.5234 - val_mse: 793.5234 - val_mae: 20.6120 - 80s/epoch - 36ms/step

Epoch 18/25

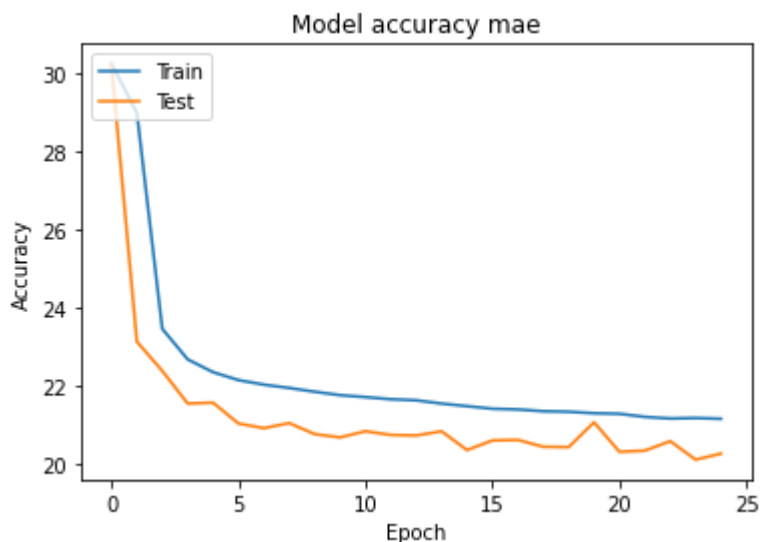
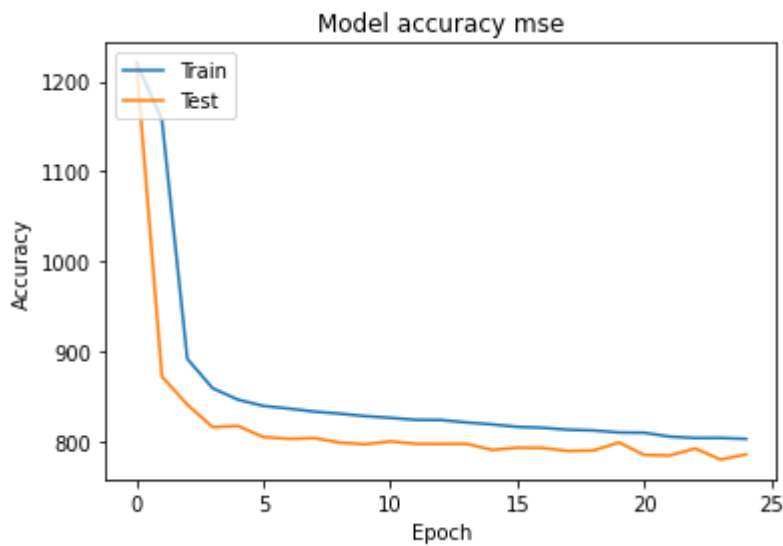
2197/2197 - 79s - loss: 813.7479 - mse: 813.7479 - mae: 21.3479 - val_loss: 790.1821 - val_mse: 790.1821 - val_mae: 20.4374 - 79s/epoch - 36ms/step

Epoch 19/25

2197/2197 - 79s - loss: 812.9620 - mse: 812.9620 - mae: 21.3346 - val_loss: 790.8671 - val_mse: 790.8671 - val_mae: 20.4274 - 79s/epoch - 36ms/step

Epoch 20/25

2197/2197 - 79s - loss: 810.6888 - mse: 810.6888 - mae: 21.2966 - val_loss: 799.6179 - val_mse: 799.6179 - val_mae: 21.0651 - 79s/epoch - 36ms/step
Epoch 21/25
2197/2197 - 79s - loss: 810.4232 - mse: 810.4232 - mae: 21.2821 - val_loss: 785.7637 - val_mse: 785.7637 - val_mae: 20.3084 - 79s/epoch - 36ms/step
Epoch 22/25
2197/2197 - 79s - loss: 806.1116 - mse: 806.1116 - mae: 21.2032 - val_loss: 785.1890 - val_mse: 785.1890 - val_mae: 20.3372 - 79s/epoch - 36ms/step
Epoch 23/25
2197/2197 - 79s - loss: 804.5637 - mse: 804.5637 - mae: 21.1610 - val_loss: 792.9572 - val_mse: 792.9572 - val_mae: 20.5797 - 79s/epoch - 36ms/step
Epoch 24/25
2197/2197 - 80s - loss: 804.6298 - mse: 804.6298 - mae: 21.1738 - val_loss: 780.7781 - val_mse: 780.7781 - val_mae: 20.1061 - 80s/epoch - 36ms/step
Epoch 25/25
2197/2197 - 79s - loss: 803.6085 - mse: 803.6085 - mae: 21.1545 - val_loss: 786.3569 - val_mse: 786.3569 - val_mae: 20.2600 - 79s/epoch - 36ms/step



In []:

```
print("Individual phase MLP")

layers = (400,200,)
shape = (400,)
model = create_mlp(shape, layers, True, "relu")
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])
epochs = 100

history = model.fit(
    x= x_train_phase, y=y_train,
    validation_data=(x_test_phase, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual phase MLP

Epoch 1/100

1099/1099 - 5s - loss: 1178.8048 - mse: 1178.8048 - mae: 29.5413 - val_loss: 904.4475 - val_mse: 904.4475 - val_mae: 24.3537 - 5s/epoch - 4ms/step

Epoch 2/100

1099/1099 - 4s - loss: 899.7714 - mse: 899.7714 - mae: 23.4799 - val_loss: 819.3149 - val_mse: 819.3149 - val_mae: 21.3965 - 4s/epoch - 4ms/step

Epoch 3/100

1099/1099 - 4s - loss: 877.3381 - mse: 877.3381 - mae: 22.8032 - val_loss: 816.1785 - val_mse: 816.1785 - val_mae: 21.1964 - 4s/epoch - 4ms/step

Epoch 4/100

1099/1099 - 4s - loss: 869.4628 - mse: 869.4628 - mae: 22.5679 - val_loss: 814.9371 - val_mse: 814.9371 - val_mae: 21.2084 - 4s/epoch - 4ms/step

Epoch 5/100

1099/1099 - 4s - loss: 861.9856 - mse: 861.9856 - mae: 22.3377 - val_loss: 813.5656 - val_mse: 813.5656 - val_mae: 21.0804 - 4s/epoch - 4ms/step

Epoch 6/100

1099/1099 - 4s - loss: 858.8546 - mse: 858.8546 - mae: 22.1942 - val_loss: 806.8504 - val_mse: 806.8504 - val_mae: 20.7616 - 4s/epoch - 4ms/step

Epoch 7/100

1099/1099 - 4s - loss: 856.7785 - mse: 856.7785 - mae: 22.0963 - val_loss: 810.7910 - val_mse: 810.7910 - val_mae: 21.0390 - 4s/epoch - 4ms/step

Epoch 8/100

1099/1099 - 4s - loss: 855.7548 - mse: 855.7548 - mae: 22.0587 - val_loss: 806.7463 - val_mse: 806.7463 - val_mae: 20.8784 - 4s/epoch - 4ms/step

Epoch 9/100

1099/1099 - 4s - loss: 855.4448 - mse: 855.4448 - mae: 22.0438 - val_loss: 819.9221 - val_mse: 819.9221 - val_mae: 21.5502 - 4s/epoch - 4ms/step

Epoch 10/100

1099/1099 - 4s - loss: 870.4656 - mse: 870.4656 - mae: 22.3710 - val_loss: 828.5594 - val_mse: 828.5594 - val_mae: 21.8186 - 4s/epoch - 4ms/step

Epoch 11/100

1099/1099 - 4s - loss: 869.5441 - mse: 869.5441 - mae: 22.3604 - val_loss: 821.2865 - val_mse: 821.2865 - val_mae: 21.4147 - 4s/epoch - 4ms/step

Epoch 12/100

1099/1099 - 4s - loss: 869.9234 - mse: 869.9234 - mae: 22.3428 - val_loss: 803.5031 - val_mse: 803.5031 - val_mae: 20.7240 - 4s/epoch - 4ms/step

Epoch 13/100

1099/1099 - 4s - loss: 869.9924 - mse: 869.9924 - mae: 22.3595 - val_loss: 818.5774 - val_mse: 818.5774 - val_mae: 21.3416 - 4s/epoch - 4ms/step

Epoch 14/100

1099/1099 - 4s - loss: 884.3769 - mse: 884.3769 - mae: 22.6770 - val_loss: 837.0696 - val_mse: 837.0696 - val_mae: 22.3369 - 4s/epoch - 4ms/step

Epoch 15/100

1099/1099 - 4s - loss: 883.5400 - mse: 883.5400 - mae: 22.6156 - val_loss: 827.1506 - val_mse: 827.1506 - val_mae: 21.8325 - 4s/epoch - 4ms/step

Epoch 16/100

1099/1099 - 4s - loss: 882.4920 - mse: 882.4920 - mae: 22.5831 - val_loss: 843.0494 - val_mse: 843.0494 - val_mae: 22.5551 - 4s/epoch - 4ms/step

Epoch 17/100

1099/1099 - 4s - loss: 881.4160 - mse: 881.4160 - mae: 22.5335 - val_loss: 854.4424 - val_mse: 854.4424 - val_mae: 23.1077 - 4s/epoch - 4ms/step

Epoch 18/100

1099/1099 - 4s - loss: 882.5658 - mse: 882.5658 - mae: 22.5591 - val_loss: 846.2364 - val_mse: 846.2364 - val_mae: 22.7384 - 4s/epoch - 4ms/step

Epoch 19/100

1099/1099 - 4s - loss: 881.0998 - mse: 881.0998 - mae: 22.5273 - val_loss: 821.5408 - val_mse: 821.5408 - val_mae: 21.5656 - 4s/epoch - 4ms/step

Epoch 20/100

1099/1099 - 4s - loss: 881.0446 - mse: 881.0446 - mae: 22.4978 - val_loss: 827.4987 - val_mse: 827.4987 - val_mae: 21.8045 - 4s/epoch - 4ms/step

Epoch 21/100

1099/1099 - 4s - loss: 881.6171 - mse: 881.6171 - mae: 22.5175 - val_loss: 829.2147 - val_mse: 829.2147 - val_mae: 21.9539 - 4s/epoch - 4ms/step

Epoch 22/100

1099/1099 - 4s - loss: 878.2720 - mse: 878.2720 - mae: 22.4585 - val_loss: 833.0135 - val_mse: 833.0135 - val_mae: 22.1200 - 4s/epoch - 4ms/step

Epoch 23/100

1099/1099 - 4s - loss: 880.4625 - mse: 880.4625 - mae: 22.5022 - val_loss: 856.4400 - val_mse: 856.4400 - val_mae: 23.2336 - 4s/epoch - 4ms/step

Epoch 24/100

1099/1099 - 4s - loss: 880.4173 - mse: 880.4173 - mae: 22.5089 - val_loss: 844.7530 - val_mse: 844.7530 - val_mae: 22.7164 - 4s/epoch - 4ms/step

Epoch 25/100

1099/1099 - 4s - loss: 880.8441 - mse: 880.8441 - mae: 22.5120 - val_loss: 839.4336 - val_mse: 839.4336 - val_mae: 22.4485 - 4s/epoch - 4ms/step

Epoch 26/100

1099/1099 - 4s - loss: 878.6341 - mse: 878.6341 - mae: 22.4731 - val_loss: 844.5924 - val_mse: 844.5924 - val_mae: 22.6805 - 4s/epoch - 4ms/step

Epoch 27/100

1099/1099 - 4s - loss: 880.3096 - mse: 880.3096 - mae: 22.4943 - val_loss: 821.0124 - val_mse: 821.0124 - val_mae: 21.6089 - 4s/epoch - 4ms/step

Epoch 28/100

1099/1099 - 4s - loss: 879.2229 - mse: 879.2229 - mae: 22.4753 - val_loss: 827.2873 - val_mse: 827.2873 - val_mae: 21.8376 - 4s/epoch - 4ms/step

Epoch 29/100

1099/1099 - 4s - loss: 877.5983 - mse: 877.5983 - mae: 22.4277 - val_loss: 823.5847 - val_mse: 823.5847 - val_mae: 21.6525 - 4s/epoch - 4ms/step

Epoch 30/100

1099/1099 - 4s - loss: 881.9590 - mse: 881.9590 - mae: 22.5140 - val_loss: 836.6258 - val_mse: 836.6258 - val_mae: 22.2890 - 4s/epoch - 4ms/step

Epoch 31/100

1099/1099 - 4s - loss: 880.3392 - mse: 880.3392 - mae: 22.4773 - val_loss: 825.2965 - val_mse: 825.2965 - val_mae: 21.7188 - 4s/epoch - 4ms/step

Epoch 32/100

1099/1099 - 4s - loss: 881.0264 - mse: 881.0264 - mae: 22.4972 - val_loss: 829.7279 - val_mse: 829.7279 - val_mae: 21.9066 - 4s/epoch - 4ms/step

Epoch 33/100

1099/1099 - 4s - loss: 880.6066 - mse: 880.6066 - mae: 22.4781 - val_loss: 838.5851 - val_mse: 838.5851 - val_mae: 22.4061 - 4s/epoch - 4ms/step

Epoch 34/100

1099/1099 - 4s - loss: 878.0634 - mse: 878.0634 - mae: 22.4318 - val_loss: 846.1062 - val_mse: 846.1062 - val_mae: 22.7566 - 4s/epoch - 4ms/step

Epoch 35/100

1099/1099 - 4s - loss: 880.7267 - mse: 880.7267 - mae: 22.4947 - val_loss: 827.2817 - val_mse: 827.2817 - val_mae: 21.8625 - 4s/epoch - 4ms/step

Epoch 36/100

1099/1099 - 4s - loss: 880.2900 - mse: 880.2900 - mae: 22.4836 - val_loss: 828.8666 - val_mse: 828.8666 - val_mae: 21.9059 - 4s/epoch - 4ms/step

Epoch 37/100

1099/1099 - 4s - loss: 882.3223 - mse: 882.3223 - mae: 22.5170 - val_loss: 831.2516 - val_mse: 831.2516 - val_mae: 22.0258 - 4s/epoch - 4ms/step

Epoch 38/100

1099/1099 - 4s - loss: 878.8930 - mse: 878.8930 - mae: 22.4521 - val_loss: 838.0955 - val_mse: 838.0955 - val_mae: 22.3926 - 4s/epoch - 4ms/step

Epoch 39/100

1099/1099 - 4s - loss: 880.7906 - mse: 880.7906 - mae: 22.4835 - val_loss: 832.8340 - val_mse: 832.8340 - val_mae: 22.1230 - 4s/epoch - 4ms/step

Epoch 40/100

1099/1099 - 4s - loss: 881.0157 - mse: 881.0157 - mae: 22.4950 - val_loss: 827.2386 - val_mse: 827.2386 - val_mae: 21.7964 - 4s/epoch - 4ms/step

Epoch 41/100

1099/1099 - 4s - loss: 879.6343 - mse: 879.6343 - mae: 22.4598 - val_loss: 858.5533 - val_mse: 858.5533 - val_mae: 23.2702 - 4s/epoch - 4ms/step
Epoch 42/100
1099/1099 - 4s - loss: 879.3191 - mse: 879.3191 - mae: 22.4506 - val_loss: 830.7242 - val_mse: 830.7242 - val_mae: 21.9869 - 4s/epoch - 4ms/step
Epoch 43/100
1099/1099 - 4s - loss: 880.8995 - mse: 880.8995 - mae: 22.4809 - val_loss: 828.3899 - val_mse: 828.3899 - val_mae: 21.8816 - 4s/epoch - 4ms/step
Epoch 44/100
1099/1099 - 4s - loss: 880.8865 - mse: 880.8865 - mae: 22.4826 - val_loss: 838.2971 - val_mse: 838.2971 - val_mae: 22.4052 - 4s/epoch - 4ms/step
Epoch 45/100
1099/1099 - 4s - loss: 879.2414 - mse: 879.2414 - mae: 22.4517 - val_loss: 843.7450 - val_mse: 843.7450 - val_mae: 22.6395 - 4s/epoch - 4ms/step
Epoch 46/100
1099/1099 - 4s - loss: 880.6681 - mse: 880.6681 - mae: 22.4893 - val_loss: 833.7660 - val_mse: 833.7660 - val_mae: 22.1947 - 4s/epoch - 4ms/step
Epoch 47/100
1099/1099 - 4s - loss: 882.9199 - mse: 882.9199 - mae: 22.5235 - val_loss: 838.9565 - val_mse: 838.9565 - val_mae: 22.4163 - 4s/epoch - 4ms/step
Epoch 48/100
1099/1099 - 4s - loss: 880.2247 - mse: 880.2247 - mae: 22.4808 - val_loss: 828.3627 - val_mse: 828.3627 - val_mae: 21.9053 - 4s/epoch - 4ms/step
Epoch 49/100
1099/1099 - 4s - loss: 882.0357 - mse: 882.0357 - mae: 22.5275 - val_loss: 824.9416 - val_mse: 824.9416 - val_mae: 21.6962 - 4s/epoch - 4ms/step
Epoch 50/100
1099/1099 - 4s - loss: 878.8900 - mse: 878.8900 - mae: 22.4503 - val_loss: 836.9022 - val_mse: 836.9022 - val_mae: 22.3382 - 4s/epoch - 4ms/step
Epoch 51/100
1099/1099 - 4s - loss: 879.7255 - mse: 879.7255 - mae: 22.4629 - val_loss: 835.1640 - val_mse: 835.1640 - val_mae: 22.2699 - 4s/epoch - 4ms/step
Epoch 52/100
1099/1099 - 4s - loss: 877.6379 - mse: 877.6379 - mae: 22.4305 - val_loss: 829.0507 - val_mse: 829.0507 - val_mae: 21.9642 - 4s/epoch - 4ms/step
Epoch 53/100
1099/1099 - 4s - loss: 880.6501 - mse: 880.6501 - mae: 22.4764 - val_loss: 842.7697 - val_mse: 842.7697 - val_mae: 22.6122 - 4s/epoch - 4ms/step
Epoch 54/100
1099/1099 - 4s - loss: 881.2848 - mse: 881.2848 - mae: 22.4982 - val_loss: 832.7761 - val_mse: 832.7761 - val_mae: 22.1298 - 4s/epoch - 4ms/step
Epoch 55/100
1099/1099 - 4s - loss: 879.0673 - mse: 879.0673 - mae: 22.4304 - val_loss: 836.5302 - val_mse: 836.5302 - val_mae: 22.3081 - 4s/epoch - 4ms/step
Epoch 56/100
1099/1099 - 4s - loss: 879.0767 - mse: 879.0767 - mae: 22.4427 - val_loss: 853.4482 - val_mse: 853.4482 - val_mae: 23.1327 - 4s/epoch - 4ms/step
Epoch 57/100
1099/1099 - 4s - loss: 880.5706 - mse: 880.5706 - mae: 22.4641 - val_loss: 837.8795 - val_mse: 837.8795 - val_mae: 22.3676 - 4s/epoch - 4ms/step
Epoch 58/100
1099/1099 - 4s - loss: 880.8407 - mse: 880.8407 - mae: 22.4656 - val_loss: 852.7392 - val_mse: 852.7392 - val_mae: 23.0645 - 4s/epoch - 4ms/step
Epoch 59/100
1099/1099 - 4s - loss: 880.1904 - mse: 880.1904 - mae: 22.4709 - val_loss: 823.5907 - val_mse: 823.5907 - val_mae: 21.6428 - 4s/epoch - 4ms/step
Epoch 60/100
1099/1099 - 4s - loss: 880.9982 - mse: 880.9982 - mae: 22.4805 - val_loss: 822.9285 - val_mse: 822.9285 - val_mae: 21.6193 - 4s/epoch - 4ms/step
Epoch 61/100
1099/1099 - 4s - loss: 880.8495 - mse: 880.8495 - mae: 22.4806 - val_loss:

824.8497 - val_mse: 824.8497 - val_mae: 21.7019 - 4s/epoch - 4ms/step
Epoch 62/100
1099/1099 - 4s - loss: 878.2570 - mse: 878.2570 - mae: 22.4142 - val_loss:
830.9634 - val_mse: 830.9634 - val_mae: 22.0250 - 4s/epoch - 4ms/step
Epoch 63/100
1099/1099 - 4s - loss: 881.4324 - mse: 881.4324 - mae: 22.4871 - val_loss:
830.7517 - val_mse: 830.7517 - val_mae: 22.0347 - 4s/epoch - 4ms/step
Epoch 64/100
1099/1099 - 4s - loss: 880.1216 - mse: 880.1216 - mae: 22.4575 - val_loss:
849.9717 - val_mse: 849.9717 - val_mae: 22.9562 - 4s/epoch - 4ms/step
Epoch 65/100
1099/1099 - 4s - loss: 881.6135 - mse: 881.6135 - mae: 22.4920 - val_loss:
826.5235 - val_mse: 826.5235 - val_mae: 21.7921 - 4s/epoch - 4ms/step
Epoch 66/100
1099/1099 - 4s - loss: 879.6982 - mse: 879.6982 - mae: 22.4497 - val_loss:
830.3492 - val_mse: 830.3492 - val_mae: 21.9742 - 4s/epoch - 4ms/step
Epoch 67/100
1099/1099 - 4s - loss: 880.8947 - mse: 880.8947 - mae: 22.4778 - val_loss:
842.4539 - val_mse: 842.4539 - val_mae: 22.5978 - 4s/epoch - 4ms/step
Epoch 68/100
1099/1099 - 4s - loss: 881.3528 - mse: 881.3528 - mae: 22.4795 - val_loss:
841.3829 - val_mse: 841.3829 - val_mae: 22.5380 - 4s/epoch - 4ms/step
Epoch 69/100
1099/1099 - 4s - loss: 880.6152 - mse: 880.6152 - mae: 22.4847 - val_loss:
846.2258 - val_mse: 846.2258 - val_mae: 22.7775 - 4s/epoch - 4ms/step
Epoch 70/100
1099/1099 - 4s - loss: 880.5629 - mse: 880.5629 - mae: 22.4735 - val_loss:
829.1835 - val_mse: 829.1835 - val_mae: 21.9555 - 4s/epoch - 4ms/step
Epoch 71/100
1099/1099 - 4s - loss: 881.9399 - mse: 881.9399 - mae: 22.4781 - val_loss:
839.4707 - val_mse: 839.4707 - val_mae: 22.4263 - 4s/epoch - 4ms/step
Epoch 72/100
1099/1099 - 4s - loss: 878.0186 - mse: 878.0186 - mae: 22.4253 - val_loss:
830.9000 - val_mse: 830.9000 - val_mae: 22.0058 - 4s/epoch - 4ms/step
Epoch 73/100
1099/1099 - 4s - loss: 879.4535 - mse: 879.4535 - mae: 22.4430 - val_loss:
823.3269 - val_mse: 823.3269 - val_mae: 21.6363 - 4s/epoch - 4ms/step
Epoch 74/100
1099/1099 - 4s - loss: 878.3035 - mse: 878.3035 - mae: 22.4391 - val_loss:
847.6500 - val_mse: 847.6500 - val_mae: 22.8609 - 4s/epoch - 4ms/step
Epoch 75/100
1099/1099 - 5s - loss: 880.6989 - mse: 880.6989 - mae: 22.4596 - val_loss:
855.7896 - val_mse: 855.7896 - val_mae: 23.2300 - 5s/epoch - 4ms/step
Epoch 76/100
1099/1099 - 4s - loss: 878.9680 - mse: 878.9680 - mae: 22.4400 - val_loss:
833.0983 - val_mse: 833.0983 - val_mae: 22.1061 - 4s/epoch - 4ms/step
Epoch 77/100
1099/1099 - 4s - loss: 878.1439 - mse: 878.1439 - mae: 22.4103 - val_loss:
834.0148 - val_mse: 834.0148 - val_mae: 22.1716 - 4s/epoch - 4ms/step
Epoch 78/100
1099/1099 - 4s - loss: 878.9178 - mse: 878.9178 - mae: 22.4459 - val_loss:
840.4341 - val_mse: 840.4341 - val_mae: 22.4708 - 4s/epoch - 4ms/step
Epoch 79/100
1099/1099 - 4s - loss: 881.6538 - mse: 881.6538 - mae: 22.4938 - val_loss:
840.0453 - val_mse: 840.0453 - val_mae: 22.5002 - 4s/epoch - 4ms/step
Epoch 80/100
1099/1099 - 4s - loss: 877.8248 - mse: 877.8248 - mae: 22.3968 - val_loss:
834.0001 - val_mse: 834.0001 - val_mae: 22.1644 - 4s/epoch - 4ms/step
Epoch 81/100
1099/1099 - 4s - loss: 878.9767 - mse: 878.9767 - mae: 22.4150 - val_loss:
868.8397 - val_mse: 868.8397 - val_mae: 23.7490 - 4s/epoch - 4ms/step

Epoch 82/100

1099/1099 - 4s - loss: 880.4111 - mse: 880.4111 - mae: 22.4667 - val_loss: 822.6824 - val_mse: 822.6824 - val_mae: 21.6050 - 4s/epoch - 4ms/step

Epoch 83/100

1099/1099 - 4s - loss: 879.4510 - mse: 879.4510 - mae: 22.4250 - val_loss: 829.1599 - val_mse: 829.1599 - val_mae: 21.9442 - 4s/epoch - 4ms/step

Epoch 84/100

1099/1099 - 5s - loss: 878.5419 - mse: 878.5419 - mae: 22.4210 - val_loss: 821.5220 - val_mse: 821.5220 - val_mae: 21.5652 - 5s/epoch - 4ms/step

Epoch 85/100

1099/1099 - 4s - loss: 878.0949 - mse: 878.0949 - mae: 22.4140 - val_loss: 824.6714 - val_mse: 824.6714 - val_mae: 21.7010 - 4s/epoch - 4ms/step

Epoch 86/100

1099/1099 - 4s - loss: 879.2643 - mse: 879.2643 - mae: 22.4404 - val_loss: 849.6341 - val_mse: 849.6341 - val_mae: 22.9205 - 4s/epoch - 4ms/step

Epoch 87/100

1099/1099 - 4s - loss: 881.6255 - mse: 881.6255 - mae: 22.4766 - val_loss: 830.2352 - val_mse: 830.2352 - val_mae: 22.0048 - 4s/epoch - 4ms/step

Epoch 88/100

1099/1099 - 4s - loss: 879.6305 - mse: 879.6305 - mae: 22.4488 - val_loss: 836.6354 - val_mse: 836.6354 - val_mae: 22.3263 - 4s/epoch - 4ms/step

Epoch 89/100

1099/1099 - 4s - loss: 877.6473 - mse: 877.6473 - mae: 22.3902 - val_loss: 826.0939 - val_mse: 826.0939 - val_mae: 21.7755 - 4s/epoch - 4ms/step

Epoch 90/100

1099/1099 - 4s - loss: 878.8193 - mse: 878.8193 - mae: 22.4223 - val_loss: 833.4097 - val_mse: 833.4097 - val_mae: 22.1936 - 4s/epoch - 4ms/step

Epoch 91/100

1099/1099 - 4s - loss: 881.9794 - mse: 881.9794 - mae: 22.4726 - val_loss: 833.2241 - val_mse: 833.2241 - val_mae: 22.0776 - 4s/epoch - 4ms/step

Epoch 92/100

1099/1099 - 4s - loss: 878.5569 - mse: 878.5569 - mae: 22.4111 - val_loss: 836.9597 - val_mse: 836.9597 - val_mae: 22.3393 - 4s/epoch - 4ms/step

Epoch 93/100

1099/1099 - 4s - loss: 880.2474 - mse: 880.2474 - mae: 22.4516 - val_loss: 832.2734 - val_mse: 832.2734 - val_mae: 22.0982 - 4s/epoch - 4ms/step

Epoch 94/100

1099/1099 - 4s - loss: 879.4999 - mse: 879.4999 - mae: 22.4420 - val_loss: 845.8476 - val_mse: 845.8476 - val_mae: 22.7722 - 4s/epoch - 4ms/step

Epoch 95/100

1099/1099 - 4s - loss: 879.0608 - mse: 879.0608 - mae: 22.4334 - val_loss: 832.1371 - val_mse: 832.1371 - val_mae: 22.0705 - 4s/epoch - 4ms/step

Epoch 96/100

1099/1099 - 4s - loss: 878.5618 - mse: 878.5618 - mae: 22.4200 - val_loss: 824.5312 - val_mse: 824.5312 - val_mae: 21.6768 - 4s/epoch - 4ms/step

Epoch 97/100

1099/1099 - 4s - loss: 879.6179 - mse: 879.6179 - mae: 22.4145 - val_loss: 829.0139 - val_mse: 829.0139 - val_mae: 21.8888 - 4s/epoch - 4ms/step

Epoch 98/100

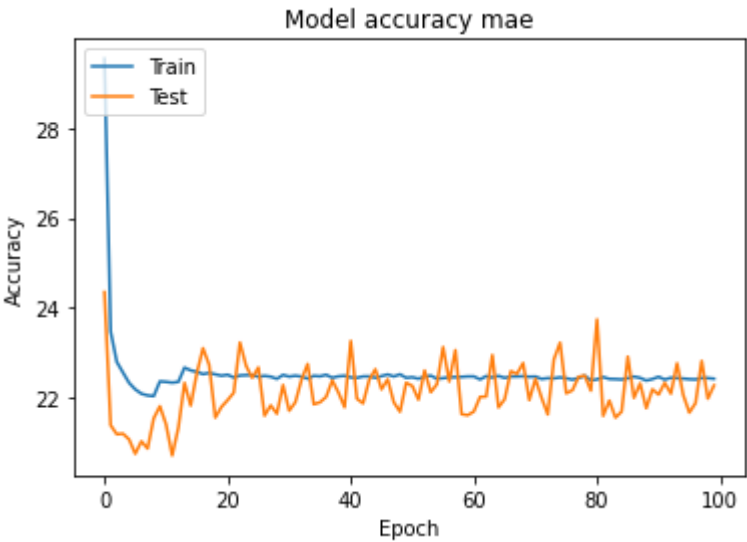
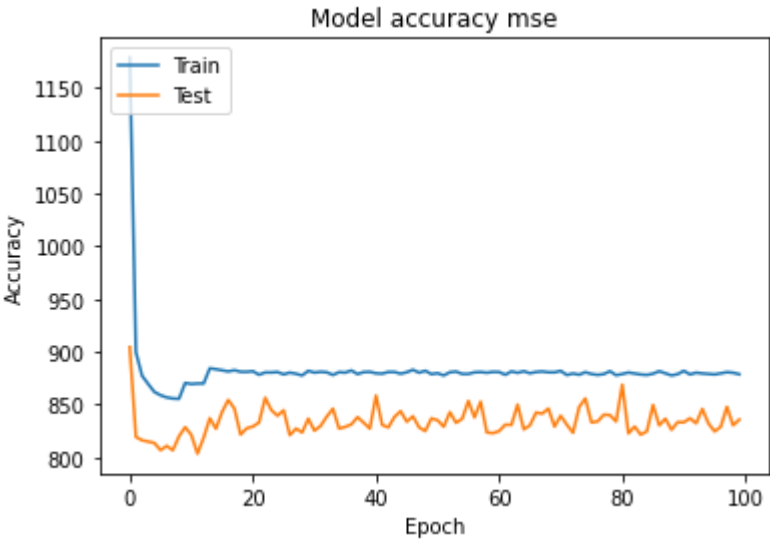
1099/1099 - 4s - loss: 880.7151 - mse: 880.7151 - mae: 22.4454 - val_loss: 847.8813 - val_mse: 847.8813 - val_mae: 22.8244 - 4s/epoch - 4ms/step

Epoch 99/100

1099/1099 - 4s - loss: 880.1879 - mse: 880.1879 - mae: 22.4441 - val_loss: 830.3206 - val_mse: 830.3206 - val_mae: 21.9879 - 4s/epoch - 4ms/step

Epoch 100/100

1099/1099 - 4s - loss: 878.7191 - mse: 878.7191 - mae: 22.4301 - val_loss: 835.7827 - val_mse: 835.7827 - val_mae: 22.2809 - 4s/epoch - 4ms/step



In []:

```
print("Individual magnitude MLP")

layers = (400,200)
shape = (400,)
epochs = 100
model = create_mlp(shape, layers, True, "relu")
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x= x_train_magnitude, y=y_train,
    validation_data=(x_test_magnitude, y_test),
    epochs=epochs, batch_size=32, verbose=2
)

display_graphs(history)
```

Individual magnitude MLP

Epoch 1/100

2197/2197 - 7s - loss: 1220.6373 - mse: 1220.6373 - mae: 30.2625 - val_loss: 1218.9465 - val_mse: 1218.9465 - val_mae: 30.2187 - 7s/epoch - 3ms/step

Epoch 2/100

2197/2197 - 7s - loss: 1216.0085 - mse: 1216.0085 - mae: 30.1885 - val_loss: 1196.8971 - val_mse: 1196.8971 - val_mae: 29.8936 - 7s/epoch - 3ms/step

Epoch 3/100

2197/2197 - 7s - loss: 1152.6525 - mse: 1152.6525 - mae: 28.9940 - val_loss: 1061.1669 - val_mse: 1061.1669 - val_mae: 27.3245 - 7s/epoch - 3ms/step

Epoch 4/100

2197/2197 - 7s - loss: 1068.0116 - mse: 1068.0116 - mae: 27.1898 - val_loss: 978.9713 - val_mse: 978.9713 - val_mae: 25.6129 - 7s/epoch - 3ms/step

Epoch 5/100

2197/2197 - 7s - loss: 1030.2446 - mse: 1030.2446 - mae: 26.3127 - val_loss: 986.0037 - val_mse: 986.0037 - val_mae: 25.6497 - 7s/epoch - 3ms/step

Epoch 6/100

2197/2197 - 7s - loss: 1010.0133 - mse: 1010.0133 - mae: 25.8316 - val_loss: 980.3610 - val_mse: 980.3610 - val_mae: 25.4937 - 7s/epoch - 3ms/step

Epoch 7/100

2197/2197 - 7s - loss: 997.6404 - mse: 997.6404 - mae: 25.5606 - val_loss: 935.4526 - val_mse: 935.4526 - val_mae: 24.6247 - 7s/epoch - 3ms/step

Epoch 8/100

2197/2197 - 13s - loss: 986.4278 - mse: 986.4278 - mae: 25.2992 - val_loss: 925.9784 - val_mse: 925.9784 - val_mae: 24.4183 - 13s/epoch - 6ms/step

Epoch 9/100

2197/2197 - 9s - loss: 983.1481 - mse: 983.1481 - mae: 25.2403 - val_loss: 904.5879 - val_mse: 904.5879 - val_mae: 23.9426 - 9s/epoch - 4ms/step

Epoch 10/100

2197/2197 - 7s - loss: 982.7324 - mse: 982.7324 - mae: 25.1803 - val_loss: 912.0182 - val_mse: 912.0182 - val_mae: 24.1593 - 7s/epoch - 3ms/step

Epoch 11/100

2197/2197 - 7s - loss: 968.7799 - mse: 968.7799 - mae: 24.9324 - val_loss: 900.6084 - val_mse: 900.6084 - val_mae: 23.8722 - 7s/epoch - 3ms/step

Epoch 12/100

2197/2197 - 7s - loss: 978.7709 - mse: 978.7709 - mae: 25.1101 - val_loss: 934.4828 - val_mse: 934.4828 - val_mae: 24.6406 - 7s/epoch - 3ms/step

Epoch 13/100

2197/2197 - 7s - loss: 986.9827 - mse: 986.9827 - mae: 25.2653 - val_loss: 902.5202 - val_mse: 902.5202 - val_mae: 23.9546 - 7s/epoch - 3ms/step

Epoch 14/100

2197/2197 - 7s - loss: 982.3340 - mse: 982.3340 - mae: 25.1776 - val_loss: 938.5814 - val_mse: 938.5814 - val_mae: 24.7988 - 7s/epoch - 3ms/step

Epoch 15/100

2197/2197 - 7s - loss: 979.5126 - mse: 979.5126 - mae: 25.1234 - val_loss: 897.5992 - val_mse: 897.5992 - val_mae: 23.8458 - 7s/epoch - 3ms/step

Epoch 16/100

2197/2197 - 7s - loss: 976.1513 - mse: 976.1513 - mae: 25.0438 - val_loss: 891.4758 - val_mse: 891.4758 - val_mae: 23.7217 - 7s/epoch - 3ms/step

Epoch 17/100

2197/2197 - 7s - loss: 971.7663 - mse: 971.7663 - mae: 24.9445 - val_loss: 920.3301 - val_mse: 920.3301 - val_mae: 24.3840 - 7s/epoch - 3ms/step

Epoch 18/100

2197/2197 - 7s - loss: 973.3300 - mse: 973.3300 - mae: 24.9805 - val_loss: 898.9843 - val_mse: 898.9843 - val_mae: 23.9370 - 7s/epoch - 3ms/step

Epoch 19/100

2197/2197 - 7s - loss: 973.2189 - mse: 973.2189 - mae: 24.9990 - val_loss: 905.6558 - val_mse: 905.6558 - val_mae: 23.9975 - 7s/epoch - 3ms/step

Epoch 20/100

2197/2197 - 7s - loss: 999.5718 - mse: 999.5718 - mae: 25.4761 - val_loss: 985.5706 - val_mse: 985.5706 - val_mae: 25.7538 - 7s/epoch - 3ms/step

Epoch 21/100

2197/2197 - 7s - loss: 1023.7968 - mse: 1023.7968 - mae: 25.9482 - val_loss: 983.4241 - val_mse: 983.4241 - val_mae: 25.6173 - 7s/epoch - 3ms/step

Epoch 22/100

2197/2197 - 7s - loss: 1017.2964 - mse: 1017.2964 - mae: 25.8141 - val_loss: 927.4474 - val_mse: 927.4474 - val_mae: 24.5125 - 7s/epoch - 3ms/step

Epoch 23/100

2197/2197 - 7s - loss: 1016.0715 - mse: 1016.0715 - mae: 25.8071 - val_loss: 934.1328 - val_mse: 934.1328 - val_mae: 24.7084 - 7s/epoch - 3ms/step

Epoch 24/100

2197/2197 - 7s - loss: 1012.7689 - mse: 1012.7689 - mae: 25.7165 - val_loss: 918.1512 - val_mse: 918.1512 - val_mae: 24.3369 - 7s/epoch - 3ms/step

Epoch 25/100

2197/2197 - 7s - loss: 1011.0839 - mse: 1011.0839 - mae: 25.6804 - val_loss: 918.0723 - val_mse: 918.0723 - val_mae: 24.3217 - 7s/epoch - 3ms/step

Epoch 26/100

2197/2197 - 7s - loss: 1012.3545 - mse: 1012.3545 - mae: 25.6886 - val_loss: 917.8530 - val_mse: 917.8530 - val_mae: 24.2931 - 7s/epoch - 3ms/step

Epoch 27/100

2197/2197 - 7s - loss: 1009.7581 - mse: 1009.7581 - mae: 25.6412 - val_loss: 910.4302 - val_mse: 910.4302 - val_mae: 24.1614 - 7s/epoch - 3ms/step

Epoch 28/100

2197/2197 - 7s - loss: 1012.8262 - mse: 1012.8262 - mae: 25.6997 - val_loss: 932.7977 - val_mse: 932.7977 - val_mae: 24.7190 - 7s/epoch - 3ms/step

Epoch 29/100

2197/2197 - 7s - loss: 1010.5347 - mse: 1010.5347 - mae: 25.6573 - val_loss: 932.4010 - val_mse: 932.4010 - val_mae: 24.7335 - 7s/epoch - 3ms/step

Epoch 30/100

2197/2197 - 7s - loss: 1010.1802 - mse: 1010.1802 - mae: 25.6424 - val_loss: 928.6591 - val_mse: 928.6591 - val_mae: 24.5529 - 7s/epoch - 3ms/step

Epoch 31/100

2197/2197 - 7s - loss: 1007.7312 - mse: 1007.7312 - mae: 25.5945 - val_loss: 944.3008 - val_mse: 944.3008 - val_mae: 24.9346 - 7s/epoch - 3ms/step

Epoch 32/100

2197/2197 - 8s - loss: 1008.8345 - mse: 1008.8345 - mae: 25.6261 - val_loss: 930.0101 - val_mse: 930.0101 - val_mae: 24.7042 - 8s/epoch - 4ms/step

Epoch 33/100

2197/2197 - 7s - loss: 1011.8918 - mse: 1011.8918 - mae: 25.6846 - val_loss: 912.3687 - val_mse: 912.3687 - val_mae: 24.1873 - 7s/epoch - 3ms/step

Epoch 34/100

2197/2197 - 8s - loss: 1004.7523 - mse: 1004.7523 - mae: 25.5321 - val_loss: 923.6444 - val_mse: 923.6444 - val_mae: 24.4796 - 8s/epoch - 4ms/step

Epoch 35/100

2197/2197 - 7s - loss: 1007.9792 - mse: 1007.9792 - mae: 25.6274 - val_loss: 914.7320 - val_mse: 914.7320 - val_mae: 24.2348 - 7s/epoch - 3ms/step

Epoch 36/100

2197/2197 - 7s - loss: 1006.1732 - mse: 1006.1732 - mae: 25.5567 - val_loss: 940.6894 - val_mse: 940.6894 - val_mae: 24.8150 - 7s/epoch - 3ms/step

Epoch 37/100

2197/2197 - 7s - loss: 1006.4597 - mse: 1006.4597 - mae: 25.5609 - val_loss: 918.2501 - val_mse: 918.2501 - val_mae: 24.3595 - 7s/epoch - 3ms/step

Epoch 38/100

2197/2197 - 8s - loss: 1003.6777 - mse: 1003.6777 - mae: 25.5143 - val_loss: 912.5076 - val_mse: 912.5076 - val_mae: 24.1769 - 8s/epoch - 4ms/step

Epoch 39/100

2197/2197 - 7s - loss: 999.5818 - mse: 999.5818 - mae: 25.4275 - val_loss: 907.7710 - val_mse: 907.7710 - val_mae: 24.0997 - 7s/epoch - 3ms/step

Epoch 40/100

2197/2197 - 7s - loss: 1003.1425 - mse: 1003.1425 - mae: 25.5002 - val_loss: 905.2870 - val_mse: 905.2870 - val_mae: 24.0700 - 7s/epoch - 3ms/step

Epoch 41/100

2197/2197 - 7s - loss: 998.3092 - mse: 998.3092 - mae: 25.3973 - val_loss: 926.6282 - val_mse: 926.6282 - val_mae: 24.5964 - 7s/epoch - 3ms/step
Epoch 42/100
2197/2197 - 7s - loss: 998.8284 - mse: 998.8284 - mae: 25.4055 - val_loss: 923.0574 - val_mse: 923.0574 - val_mae: 24.4977 - 7s/epoch - 3ms/step
Epoch 43/100
2197/2197 - 7s - loss: 1000.2788 - mse: 1000.2788 - mae: 25.4519 - val_loss: 913.4707 - val_mse: 913.4707 - val_mae: 24.2206 - 7s/epoch - 3ms/step
Epoch 44/100
2197/2197 - 8s - loss: 998.4695 - mse: 998.4695 - mae: 25.3746 - val_loss: 910.7852 - val_mse: 910.7852 - val_mae: 24.1917 - 8s/epoch - 4ms/step
Epoch 45/100
2197/2197 - 7s - loss: 997.5363 - mse: 997.5363 - mae: 25.3973 - val_loss: 907.7659 - val_mse: 907.7659 - val_mae: 24.1285 - 7s/epoch - 3ms/step
Epoch 46/100
2197/2197 - 7s - loss: 998.1850 - mse: 998.1850 - mae: 25.4033 - val_loss: 918.6212 - val_mse: 918.6212 - val_mae: 24.3200 - 7s/epoch - 3ms/step
Epoch 47/100
2197/2197 - 7s - loss: 997.6413 - mse: 997.6413 - mae: 25.3979 - val_loss: 941.8212 - val_mse: 941.8212 - val_mae: 24.9737 - 7s/epoch - 3ms/step
Epoch 48/100
2197/2197 - 7s - loss: 998.3562 - mse: 998.3562 - mae: 25.4156 - val_loss: 910.5247 - val_mse: 910.5247 - val_mae: 24.1592 - 7s/epoch - 3ms/step
Epoch 49/100
2197/2197 - 8s - loss: 996.7648 - mse: 996.7648 - mae: 25.3557 - val_loss: 917.5327 - val_mse: 917.5327 - val_mae: 24.3404 - 8s/epoch - 4ms/step
Epoch 50/100
2197/2197 - 7s - loss: 998.1552 - mse: 998.1552 - mae: 25.3861 - val_loss: 919.1124 - val_mse: 919.1124 - val_mae: 24.3251 - 7s/epoch - 3ms/step
Epoch 51/100
2197/2197 - 7s - loss: 997.5471 - mse: 997.5471 - mae: 25.3974 - val_loss: 928.0488 - val_mse: 928.0488 - val_mae: 24.4974 - 7s/epoch - 3ms/step
Epoch 52/100
2197/2197 - 7s - loss: 994.9979 - mse: 994.9979 - mae: 25.3442 - val_loss: 913.8755 - val_mse: 913.8755 - val_mae: 24.1962 - 7s/epoch - 3ms/step
Epoch 53/100
2197/2197 - 7s - loss: 992.8383 - mse: 992.8383 - mae: 25.2706 - val_loss: 918.1154 - val_mse: 918.1154 - val_mae: 24.3917 - 7s/epoch - 3ms/step
Epoch 54/100
2197/2197 - 7s - loss: 997.7430 - mse: 997.7430 - mae: 25.3737 - val_loss: 901.3516 - val_mse: 901.3516 - val_mae: 23.9545 - 7s/epoch - 3ms/step
Epoch 55/100
2197/2197 - 8s - loss: 996.2393 - mse: 996.2393 - mae: 25.3292 - val_loss: 935.8342 - val_mse: 935.8342 - val_mae: 24.7422 - 8s/epoch - 3ms/step
Epoch 56/100
2197/2197 - 7s - loss: 995.9583 - mse: 995.9583 - mae: 25.3528 - val_loss: 908.8882 - val_mse: 908.8882 - val_mae: 24.1031 - 7s/epoch - 3ms/step
Epoch 57/100
2197/2197 - 7s - loss: 993.4190 - mse: 993.4190 - mae: 25.3040 - val_loss: 909.2479 - val_mse: 909.2479 - val_mae: 24.1897 - 7s/epoch - 3ms/step
Epoch 58/100
2197/2197 - 7s - loss: 993.5285 - mse: 993.5285 - mae: 25.3242 - val_loss: 912.6870 - val_mse: 912.6870 - val_mae: 24.1854 - 7s/epoch - 3ms/step
Epoch 59/100
2197/2197 - 7s - loss: 988.5712 - mse: 988.5712 - mae: 25.1983 - val_loss: 907.7223 - val_mse: 907.7223 - val_mae: 24.0959 - 7s/epoch - 3ms/step
Epoch 60/100
2197/2197 - 8s - loss: 995.9176 - mse: 995.9176 - mae: 25.3601 - val_loss: 918.9099 - val_mse: 918.9099 - val_mae: 24.3979 - 8s/epoch - 4ms/step
Epoch 61/100
2197/2197 - 7s - loss: 993.8567 - mse: 993.8567 - mae: 25.3058 - val_loss:

910.0279 - val_mse: 910.0279 - val_mae: 24.0959 - 7s/epoch - 3ms/step
Epoch 62/100
2197/2197 - 8s - loss: 996.1813 - mse: 996.1813 - mae: 25.3472 - val_loss:
900.9333 - val_mse: 900.9333 - val_mae: 23.9662 - 8s/epoch - 4ms/step
Epoch 63/100
2197/2197 - 7s - loss: 991.1199 - mse: 991.1199 - mae: 25.2395 - val_loss:
903.6221 - val_mse: 903.6221 - val_mae: 24.0100 - 7s/epoch - 3ms/step
Epoch 64/100
2197/2197 - 8s - loss: 993.1451 - mse: 993.1451 - mae: 25.2704 - val_loss:
903.5701 - val_mse: 903.5701 - val_mae: 24.0437 - 8s/epoch - 3ms/step
Epoch 65/100
2197/2197 - 7s - loss: 993.4503 - mse: 993.4503 - mae: 25.2875 - val_loss:
919.0563 - val_mse: 919.0563 - val_mae: 24.3922 - 7s/epoch - 3ms/step
Epoch 66/100
2197/2197 - 7s - loss: 990.9920 - mse: 990.9920 - mae: 25.2494 - val_loss:
898.5410 - val_mse: 898.5410 - val_mae: 23.9278 - 7s/epoch - 3ms/step
Epoch 67/100
2197/2197 - 7s - loss: 992.4626 - mse: 992.4626 - mae: 25.2742 - val_loss:
897.3444 - val_mse: 897.3444 - val_mae: 23.8890 - 7s/epoch - 3ms/step
Epoch 68/100
2197/2197 - 7s - loss: 990.6195 - mse: 990.6195 - mae: 25.2285 - val_loss:
897.4887 - val_mse: 897.4887 - val_mae: 23.9209 - 7s/epoch - 3ms/step
Epoch 69/100
2197/2197 - 8s - loss: 991.0278 - mse: 991.0278 - mae: 25.2434 - val_loss:
902.6273 - val_mse: 902.6273 - val_mae: 24.0299 - 8s/epoch - 3ms/step
Epoch 70/100
2197/2197 - 7s - loss: 993.1011 - mse: 993.1011 - mae: 25.2949 - val_loss:
901.1216 - val_mse: 901.1216 - val_mae: 23.9260 - 7s/epoch - 3ms/step
Epoch 71/100
2197/2197 - 7s - loss: 987.8505 - mse: 987.8505 - mae: 25.1947 - val_loss:
892.8495 - val_mse: 892.8495 - val_mae: 23.7832 - 7s/epoch - 3ms/step
Epoch 72/100
2197/2197 - 7s - loss: 992.2344 - mse: 992.2344 - mae: 25.2663 - val_loss:
918.7436 - val_mse: 918.7436 - val_mae: 24.3624 - 7s/epoch - 3ms/step
Epoch 73/100
2197/2197 - 7s - loss: 992.0766 - mse: 992.0766 - mae: 25.2521 - val_loss:
901.6283 - val_mse: 901.6283 - val_mae: 23.9314 - 7s/epoch - 3ms/step
Epoch 74/100
2197/2197 - 7s - loss: 989.8717 - mse: 989.8717 - mae: 25.2114 - val_loss:
896.5222 - val_mse: 896.5222 - val_mae: 23.8403 - 7s/epoch - 3ms/step
Epoch 75/100
2197/2197 - 8s - loss: 989.3483 - mse: 989.3483 - mae: 25.2273 - val_loss:
908.3932 - val_mse: 908.3932 - val_mae: 24.1717 - 8s/epoch - 3ms/step
Epoch 76/100
2197/2197 - 7s - loss: 985.2496 - mse: 985.2496 - mae: 25.1423 - val_loss:
894.1533 - val_mse: 894.1533 - val_mae: 23.7985 - 7s/epoch - 3ms/step
Epoch 77/100
2197/2197 - 8s - loss: 986.7079 - mse: 986.7079 - mae: 25.1607 - val_loss:
889.3544 - val_mse: 889.3544 - val_mae: 23.6768 - 8s/epoch - 4ms/step
Epoch 78/100
2197/2197 - 8s - loss: 989.0031 - mse: 989.0031 - mae: 25.1850 - val_loss:
896.3224 - val_mse: 896.3224 - val_mae: 23.8319 - 8s/epoch - 3ms/step
Epoch 79/100
2197/2197 - 7s - loss: 986.9152 - mse: 986.9152 - mae: 25.1548 - val_loss:
926.1289 - val_mse: 926.1289 - val_mae: 24.5838 - 7s/epoch - 3ms/step
Epoch 80/100
2197/2197 - 7s - loss: 989.3970 - mse: 989.3970 - mae: 25.2002 - val_loss:
907.2451 - val_mse: 907.2451 - val_mae: 24.1412 - 7s/epoch - 3ms/step
Epoch 81/100
2197/2197 - 7s - loss: 985.9930 - mse: 985.9930 - mae: 25.1709 - val_loss:
896.3280 - val_mse: 896.3280 - val_mae: 23.8586 - 7s/epoch - 3ms/step

Epoch 82/100

2197/2197 - 7s - loss: 986.7072 - mse: 986.7072 - mae: 25.1688 - val_loss: 904.1029 - val_mse: 904.1029 - val_mae: 24.0237 - 7s/epoch - 3ms/step

Epoch 83/100

2197/2197 - 7s - loss: 987.1023 - mse: 987.1023 - mae: 25.1662 - val_loss: 894.9587 - val_mse: 894.9587 - val_mae: 23.8078 - 7s/epoch - 3ms/step

Epoch 84/100

2197/2197 - 7s - loss: 987.5228 - mse: 987.5228 - mae: 25.1787 - val_loss: 902.3145 - val_mse: 902.3145 - val_mae: 23.9887 - 7s/epoch - 3ms/step

Epoch 85/100

2197/2197 - 7s - loss: 985.5182 - mse: 985.5182 - mae: 25.1416 - val_loss: 904.7166 - val_mse: 904.7166 - val_mae: 24.0728 - 7s/epoch - 3ms/step

Epoch 86/100

2197/2197 - 7s - loss: 987.4702 - mse: 987.4702 - mae: 25.1889 - val_loss: 927.7195 - val_mse: 927.7195 - val_mae: 24.6566 - 7s/epoch - 3ms/step

Epoch 87/100

2197/2197 - 7s - loss: 988.5541 - mse: 988.5541 - mae: 25.1987 - val_loss: 909.8726 - val_mse: 909.8726 - val_mae: 24.2435 - 7s/epoch - 3ms/step

Epoch 88/100

2197/2197 - 7s - loss: 987.1520 - mse: 987.1520 - mae: 25.1684 - val_loss: 901.6262 - val_mse: 901.6262 - val_mae: 23.9352 - 7s/epoch - 3ms/step

Epoch 89/100

2197/2197 - 7s - loss: 985.6617 - mse: 985.6617 - mae: 25.1493 - val_loss: 911.7567 - val_mse: 911.7567 - val_mae: 24.1525 - 7s/epoch - 3ms/step

Epoch 90/100

2197/2197 - 8s - loss: 983.7745 - mse: 983.7745 - mae: 25.0981 - val_loss: 929.5363 - val_mse: 929.5363 - val_mae: 24.6085 - 8s/epoch - 4ms/step

Epoch 91/100

2197/2197 - 7s - loss: 989.4543 - mse: 989.4543 - mae: 25.2180 - val_loss: 907.2532 - val_mse: 907.2532 - val_mae: 24.1001 - 7s/epoch - 3ms/step

Epoch 92/100

2197/2197 - 8s - loss: 985.8809 - mse: 985.8809 - mae: 25.1339 - val_loss: 892.8086 - val_mse: 892.8086 - val_mae: 23.8079 - 8s/epoch - 4ms/step

Epoch 93/100

2197/2197 - 7s - loss: 986.0638 - mse: 986.0638 - mae: 25.1559 - val_loss: 899.8484 - val_mse: 899.8484 - val_mae: 23.9512 - 7s/epoch - 3ms/step

Epoch 94/100

2197/2197 - 7s - loss: 987.6514 - mse: 987.6514 - mae: 25.1792 - val_loss: 893.2443 - val_mse: 893.2443 - val_mae: 23.7405 - 7s/epoch - 3ms/step

Epoch 95/100

2197/2197 - 7s - loss: 982.4953 - mse: 982.4953 - mae: 25.0893 - val_loss: 895.9167 - val_mse: 895.9167 - val_mae: 23.8608 - 7s/epoch - 3ms/step

Epoch 96/100

2197/2197 - 8s - loss: 985.5306 - mse: 985.5306 - mae: 25.1299 - val_loss: 905.2233 - val_mse: 905.2233 - val_mae: 24.0854 - 8s/epoch - 4ms/step

Epoch 97/100

2197/2197 - 8s - loss: 981.7521 - mse: 981.7521 - mae: 25.0513 - val_loss: 887.9090 - val_mse: 887.9090 - val_mae: 23.6487 - 8s/epoch - 4ms/step

Epoch 98/100

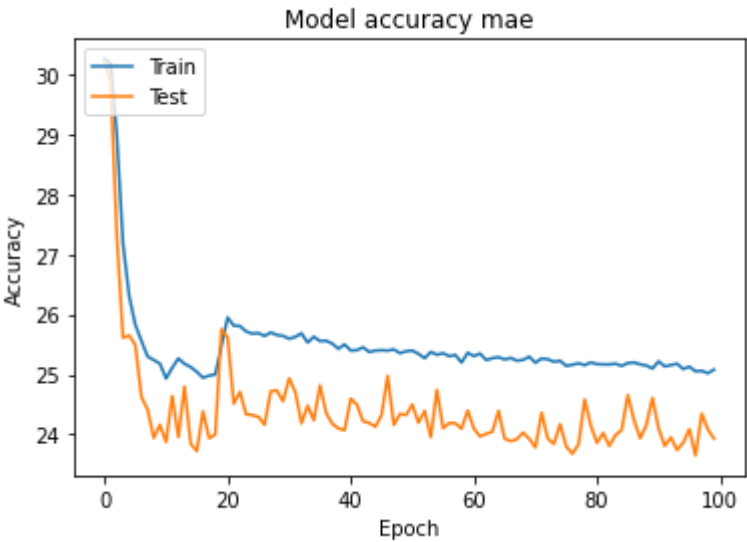
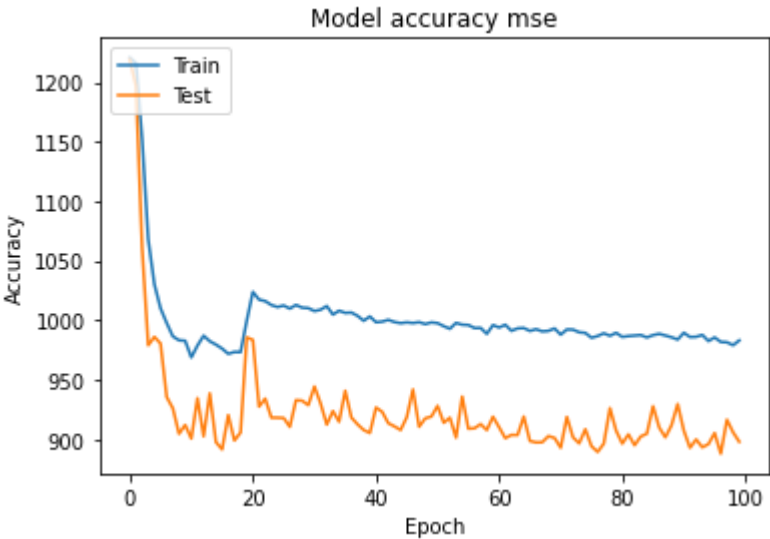
2197/2197 - 7s - loss: 981.4842 - mse: 981.4842 - mae: 25.0603 - val_loss: 916.4025 - val_mse: 916.4025 - val_mae: 24.3456 - 7s/epoch - 3ms/step

Epoch 99/100

2197/2197 - 7s - loss: 979.0071 - mse: 979.0071 - mae: 25.0200 - val_loss: 905.7991 - val_mse: 905.7991 - val_mae: 24.0860 - 7s/epoch - 3ms/step

Epoch 100/100

2197/2197 - 7s - loss: 983.0318 - mse: 983.0318 - mae: 25.0796 - val_loss: 897.9091 - val_mse: 897.9091 - val_mae: 23.9299 - 7s/epoch - 3ms/step



In []:

```
print("Individual phase 1D CNN")

shape=(400,1)
filters=(16,16)
layers=(100,)
epochs = 25
model = create_1d_cnn(shape, True, filters, layers, 'relu')
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse','mae'])

history = model.fit(
    x= x_train_phase, y=y_train,
    validation_data=(x_test_phase, y_test),
    epochs=epochs, batch_size=32, verbose=2
)

display_graphs(history)
```

Individual phase 1D CNN

Epoch 1/25

2197/2197 - 21s - loss: 1220.6075 - mse: 1220.6075 - mae: 30.2637 - val_loss: 1219.1757 - val_mse: 1219.1757 - val_mae: 30.2259 - 21s/epoch - 10ms/step

Epoch 2/25

2197/2197 - 21s - loss: 1220.5579 - mse: 1220.5579 - mae: 30.2631 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2260 - 21s/epoch - 10ms/step

Epoch 3/25

2197/2197 - 21s - loss: 1220.5598 - mse: 1220.5598 - mae: 30.2630 - val_loss: 1219.1742 - val_mse: 1219.1742 - val_mae: 30.2258 - 21s/epoch - 10ms/step

Epoch 4/25

2197/2197 - 21s - loss: 1220.5596 - mse: 1220.5596 - mae: 30.2631 - val_loss: 1219.1736 - val_mse: 1219.1736 - val_mae: 30.2258 - 21s/epoch - 10ms/step

Epoch 5/25

2197/2197 - 21s - loss: 1220.5566 - mse: 1220.5566 - mae: 30.2630 - val_loss: 1219.1742 - val_mse: 1219.1742 - val_mae: 30.2258 - 21s/epoch - 10ms/step

Epoch 6/25

2197/2197 - 22s - loss: 1220.5583 - mse: 1220.5583 - mae: 30.2629 - val_loss: 1219.1753 - val_mse: 1219.1753 - val_mae: 30.2259 - 22s/epoch - 10ms/step

Epoch 7/25

2197/2197 - 22s - loss: 1220.5588 - mse: 1220.5588 - mae: 30.2629 - val_loss: 1219.1743 - val_mse: 1219.1743 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 8/25

2197/2197 - 22s - loss: 1220.5564 - mse: 1220.5564 - mae: 30.2630 - val_loss: 1219.1757 - val_mse: 1219.1757 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 9/25

2197/2197 - 23s - loss: 1220.5559 - mse: 1220.5559 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 23s/epoch - 11ms/step

Epoch 10/25

2197/2197 - 22s - loss: 1220.5565 - mse: 1220.5565 - mae: 30.2629 - val_loss: 1219.1757 - val_mse: 1219.1757 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 11/25

2197/2197 - 22s - loss: 1220.5562 - mse: 1220.5562 - mae: 30.2629 - val_loss: 1219.1742 - val_mse: 1219.1742 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 12/25

2197/2197 - 23s - loss: 1220.5569 - mse: 1220.5569 - mae: 30.2628 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2258 - 23s/epoch - 10ms/step

Epoch 13/25

2197/2197 - 23s - loss: 1220.5562 - mse: 1220.5562 - mae: 30.2629 - val_loss: 1219.1737 - val_mse: 1219.1737 - val_mae: 30.2258 - 23s/epoch - 10ms/step

Epoch 14/25

2197/2197 - 23s - loss: 1220.5546 - mse: 1220.5546 - mae: 30.2630 - val_loss: 1219.1730 - val_mse: 1219.1730 - val_mae: 30.2258 - 23s/epoch - 10ms/step

Epoch 15/25

2197/2197 - 22s - loss: 1220.5568 - mse: 1220.5568 - mae: 30.2629 - val_loss: 1219.1731 - val_mse: 1219.1731 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 16/25

2197/2197 - 22s - loss: 1220.5562 - mse: 1220.5562 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2259 - 22s/epoch - 10ms/step

Epoch 17/25

2197/2197 - 22s - loss: 1220.5551 - mse: 1220.5551 - mae: 30.2629 - val_loss: 1219.1757 - val_mse: 1219.1757 - val_mae: 30.2259 - 22s/epoch - 10ms/step

Epoch 18/25

2197/2197 - 23s - loss: 1220.5573 - mse: 1220.5573 - mae: 30.2630 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2258 - 23s/epoch - 11ms/step

Epoch 19/25

2197/2197 - 22s - loss: 1220.5560 - mse: 1220.5560 - mae: 30.2630 - val_loss: 1219.1753 - val_mse: 1219.1753 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 20/25

2197/2197 - 22s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1731 - val_mse: 1219.1731 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 21/25

2197/2197 - 21s - loss: 1220.5579 - mse: 1220.5579 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2258 - 21s/epoch - 10ms/step

Epoch 22/25

2197/2197 - 22s - loss: 1220.5577 - mse: 1220.5577 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 22s/epoch - 10ms/step

Epoch 23/25

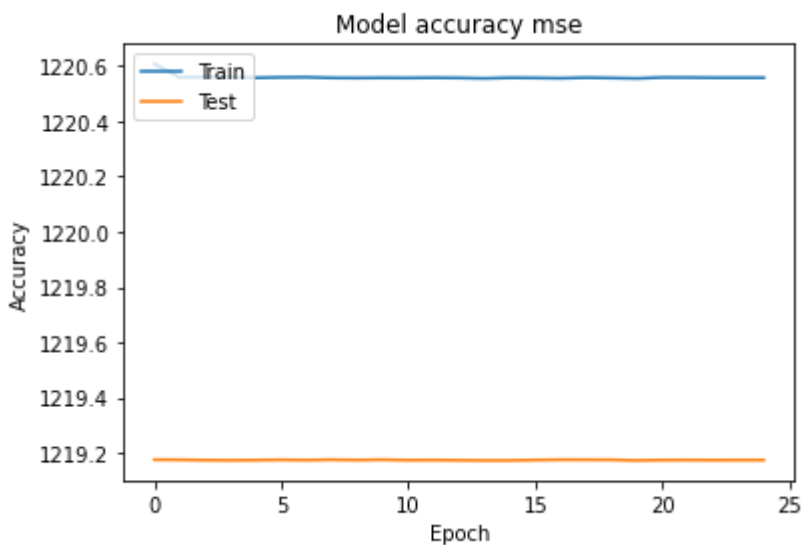
2197/2197 - 22s - loss: 1220.5570 - mse: 1220.5570 - mae: 30.2629 - val_loss: 1219.1742 - val_mse: 1219.1742 - val_mae: 30.2258 - 22s/epoch - 10ms/step

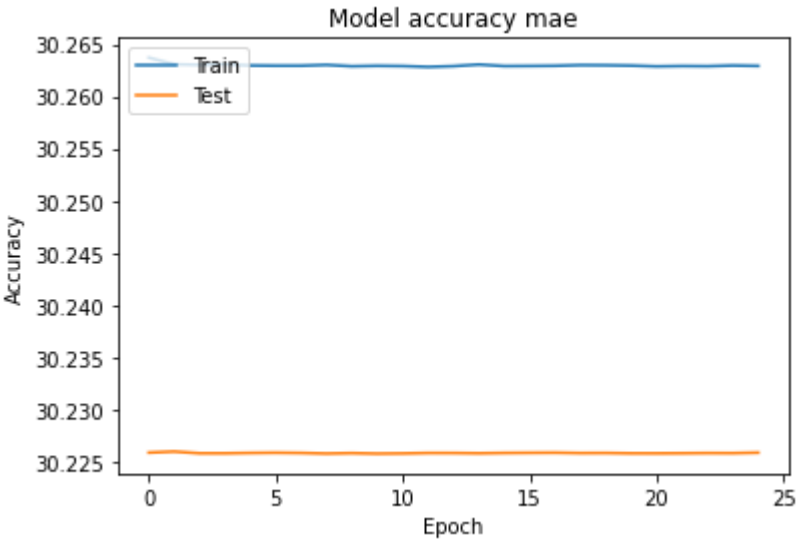
Epoch 24/25

2197/2197 - 23s - loss: 1220.5570 - mse: 1220.5570 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2258 - 23s/epoch - 10ms/step

Epoch 25/25

2197/2197 - 22s - loss: 1220.5569 - mse: 1220.5569 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2259 - 22s/epoch - 10ms/step





In []:

```
print("Individual magnitude 1D CNN")
shape=(400,1)
filters=(64,64)
layers=(100,)
epochs = 25
model = create_1d_cnn(shape, True, filters, layers, 'relu')
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse','mae'])

history = model.fit(
    x= x_train_magnitude, y=y_train,
    validation_data=(x_test_magnitude, y_test),
    epochs=epochs, batch_size=32, verbose=2
)

display_graphs(history)
```

Individual magnitude 1D CNN

Epoch 1/25

2197/2197 - 51s - loss: 1120.1287 - mse: 1120.1287 - mae: 28.2986 - val_loss: 913.3382 - val_mse: 913.3382 - val_mae: 24.1304 - 51s/epoch - 23ms/step

Epoch 2/25

2197/2197 - 50s - loss: 932.9537 - mse: 932.9537 - mae: 24.4868 - val_loss: 862.9015 - val_mse: 862.9015 - val_mae: 22.8238 - 50s/epoch - 23ms/step

Epoch 3/25

2197/2197 - 50s - loss: 895.5186 - mse: 895.5186 - mae: 23.5713 - val_loss: 834.2013 - val_mse: 834.2013 - val_mae: 21.9902 - 50s/epoch - 23ms/step

Epoch 4/25

2197/2197 - 51s - loss: 874.1041 - mse: 874.1041 - mae: 23.0520 - val_loss: 820.6949 - val_mse: 820.6949 - val_mae: 21.4930 - 51s/epoch - 23ms/step

Epoch 5/25

2197/2197 - 53s - loss: 866.4921 - mse: 866.4921 - mae: 22.8113 - val_loss: 813.8534 - val_mse: 813.8534 - val_mae: 21.2469 - 53s/epoch - 24ms/step

Epoch 6/25

2197/2197 - 50s - loss: 856.9814 - mse: 856.9814 - mae: 22.5688 - val_loss: 808.2625 - val_mse: 808.2625 - val_mae: 21.0133 - 50s/epoch - 23ms/step

Epoch 7/25

2197/2197 - 51s - loss: 851.4037 - mse: 851.4037 - mae: 22.4022 - val_loss: 805.3831 - val_mse: 805.3831 - val_mae: 20.9573 - 51s/epoch - 23ms/step

Epoch 8/25

2197/2197 - 51s - loss: 840.9355 - mse: 840.9355 - mae: 22.1333 - val_loss: 801.5881 - val_mse: 801.5881 - val_mae: 20.8105 - 51s/epoch - 23ms/step

Epoch 9/25

2197/2197 - 51s - loss: 838.3653 - mse: 838.3653 - mae: 22.0384 - val_loss: 800.7048 - val_mse: 800.7048 - val_mae: 20.7677 - 51s/epoch - 23ms/step

Epoch 10/25

2197/2197 - 51s - loss: 834.2053 - mse: 834.2053 - mae: 21.9143 - val_loss: 801.0242 - val_mse: 801.0242 - val_mae: 20.8528 - 51s/epoch - 23ms/step

Epoch 11/25

2197/2197 - 50s - loss: 830.5430 - mse: 830.5430 - mae: 21.8417 - val_loss: 796.0657 - val_mse: 796.0657 - val_mae: 20.5832 - 50s/epoch - 23ms/step

Epoch 12/25

2197/2197 - 51s - loss: 829.5330 - mse: 829.5330 - mae: 21.7844 - val_loss: 797.8635 - val_mse: 797.8635 - val_mae: 20.7466 - 51s/epoch - 23ms/step

Epoch 13/25

2197/2197 - 50s - loss: 826.0372 - mse: 826.0372 - mae: 21.6993 - val_loss: 795.3427 - val_mse: 795.3427 - val_mae: 20.6273 - 50s/epoch - 23ms/step

Epoch 14/25

2197/2197 - 51s - loss: 826.6191 - mse: 826.6191 - mae: 21.6913 - val_loss: 799.6348 - val_mse: 799.6348 - val_mae: 20.8334 - 51s/epoch - 23ms/step

Epoch 15/25

2197/2197 - 51s - loss: 825.0281 - mse: 825.0281 - mae: 21.6495 - val_loss: 801.2826 - val_mse: 801.2826 - val_mae: 21.0084 - 51s/epoch - 23ms/step

Epoch 16/25

2197/2197 - 50s - loss: 822.9753 - mse: 822.9753 - mae: 21.6143 - val_loss: 795.8555 - val_mse: 795.8555 - val_mae: 20.6550 - 50s/epoch - 23ms/step

Epoch 17/25

2197/2197 - 51s - loss: 821.3815 - mse: 821.3815 - mae: 21.5776 - val_loss: 800.6804 - val_mse: 800.6804 - val_mae: 20.9395 - 51s/epoch - 23ms/step

Epoch 18/25

2197/2197 - 50s - loss: 821.6725 - mse: 821.6725 - mae: 21.5829 - val_loss: 796.1881 - val_mse: 796.1881 - val_mae: 20.7546 - 50s/epoch - 23ms/step

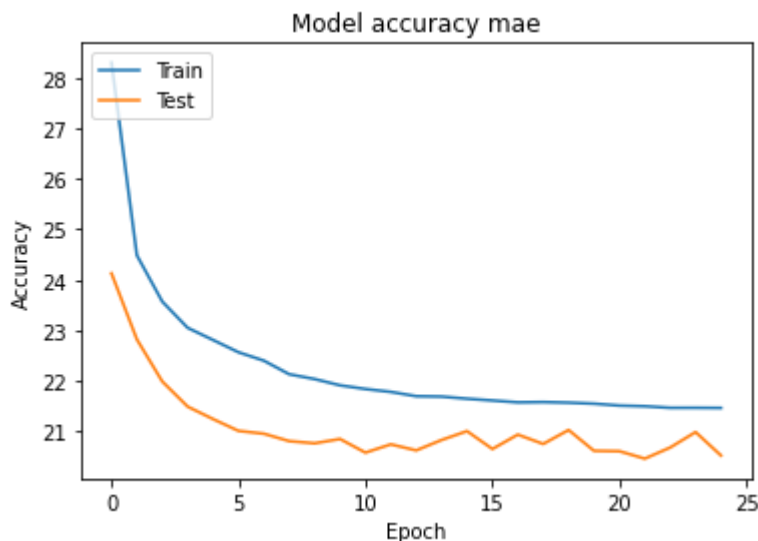
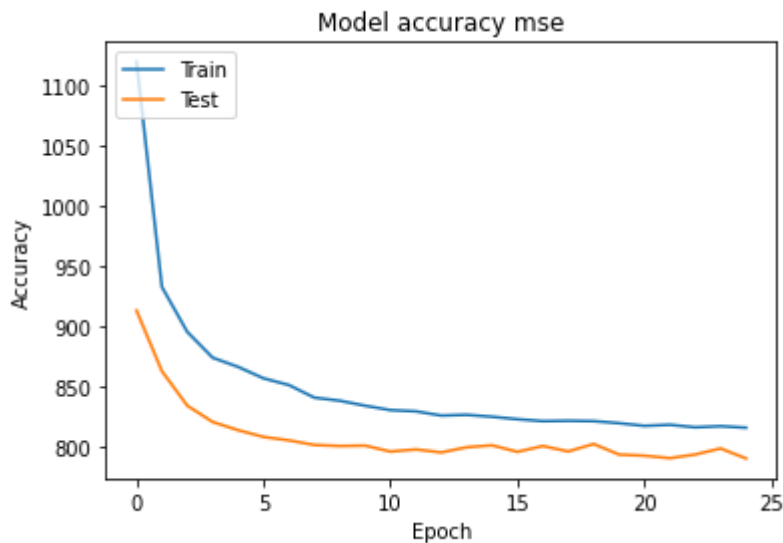
Epoch 19/25

2197/2197 - 51s - loss: 821.3787 - mse: 821.3787 - mae: 21.5713 - val_loss: 802.3741 - val_mse: 802.3741 - val_mae: 21.0305 - 51s/epoch - 23ms/step

Epoch 20/25

2197/2197 - 51s - loss: 819.6779 - mse: 819.6779 - mae: 21.5514 - val_loss:

s: 793.5825 - val_mse: 793.5825 - val_mae: 20.6188 - 51s/epoch - 23ms/step
 Epoch 21/25
 2197/2197 - 50s - loss: 817.4601 - mse: 817.4601 - mae: 21.5138 - val_loss: 792.6459 - val_mse: 792.6459 - val_mae: 20.6114 - 50s/epoch - 23ms/step
 Epoch 22/25
 2197/2197 - 50s - loss: 818.3578 - mse: 818.3578 - mae: 21.5005 - val_loss: 790.5941 - val_mse: 790.5941 - val_mae: 20.4639 - 50s/epoch - 23ms/step
 Epoch 23/25
 2197/2197 - 50s - loss: 816.2393 - mse: 816.2393 - mae: 21.4695 - val_loss: 793.6315 - val_mse: 793.6315 - val_mae: 20.6838 - 50s/epoch - 23ms/step
 Epoch 24/25
 2197/2197 - 52s - loss: 817.1477 - mse: 817.1477 - mae: 21.4697 - val_loss: 798.6484 - val_mse: 798.6484 - val_mae: 20.9894 - 52s/epoch - 24ms/step
 Epoch 25/25
 2197/2197 - 51s - loss: 815.9229 - mse: 815.9229 - mae: 21.4668 - val_loss: 790.3333 - val_mse: 790.3333 - val_mae: 20.5262 - 51s/epoch - 23ms/step



2D CNN

The 2D CNN will only be performed against the data from the 2-by-2 antenna without PCA. Dimensionality reduction conflicts with the 2D CNN.

In []:

```
antenna_num = 2

magnitude = pd.read_csv('/content/drive/MyDrive/train_magnitude.csv', header=None).to_numpy()
output_data = pd.read_csv('/content/drive/MyDrive/train_outputs.csv', header=None).to_numpy()
phase = pd.read_csv('/content/drive/MyDrive/train_phase.csv', header=None).to_numpy()

data = load_data_cnn(phase, magnitude, output_data, antenna_num)
phase_data = data[0]
magnitude_data = data[1]
output_data = data[2]

data_split = split_test_train(phase_data, magnitude_data, output_data, 0.4)
x_train_magnitude = data_split[0]
x_test_magnitude = data_split[1]
x_train_phase = data_split[2]
x_test_phase = data_split[3]
y_train = data_split[4][:,0:2]
y_test = data_split[5][:,0:2]
```


In []:

```
epochs = 25
filters=(64,32,16)
lr = 0.001
opt = Adam(learning_rate=lr)
regress=False

phase = create_2d_cnn(100, 4, 1, filters, regress, "relu")
magnitude = create_2d_cnn(100, 4, 1, filters, regress, "relu")

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
x=[x_train_magnitude, x_train_phase], y=y_train,
  validation_data=(x_test_magnitude, x_test_phase), y_test),
  epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Epoch 1/25

1099/1099 - 162s - loss: 870.2733 - mse: 870.2733 - mae: 22.5217 - val_loss: 797.9747 - val_mse: 797.9747 - val_mae: 20.3381 - 162s/epoch - 148ms/step

Epoch 2/25

1099/1099 - 162s - loss: 786.3965 - mse: 786.3965 - mae: 20.5208 - val_loss: 733.0698 - val_mse: 733.0698 - val_mae: 18.4851 - 162s/epoch - 147ms/step

Epoch 3/25

1099/1099 - 161s - loss: 750.9487 - mse: 750.9487 - mae: 19.8003 - val_loss: 705.0529 - val_mse: 705.0529 - val_mae: 17.7261 - 161s/epoch - 147ms/step

Epoch 4/25

1099/1099 - 162s - loss: 725.7965 - mse: 725.7965 - mae: 19.3114 - val_loss: 742.4571 - val_mse: 742.4571 - val_mae: 17.8547 - 162s/epoch - 147ms/step

Epoch 5/25

1099/1099 - 162s - loss: 713.2769 - mse: 713.2769 - mae: 19.0653 - val_loss: 652.0582 - val_mse: 652.0582 - val_mae: 16.9853 - 162s/epoch - 147ms/step

Epoch 6/25

1099/1099 - 161s - loss: 695.9887 - mse: 695.9887 - mae: 18.6012 - val_loss: 636.5539 - val_mse: 636.5539 - val_mae: 16.4625 - 161s/epoch - 147ms/step

Epoch 7/25

1099/1099 - 160s - loss: 666.6690 - mse: 666.6690 - mae: 17.9857 - val_loss: 674.7387 - val_mse: 674.7387 - val_mae: 15.7624 - 160s/epoch - 146ms/step

Epoch 8/25

1099/1099 - 166s - loss: 642.1755 - mse: 642.1755 - mae: 17.4326 - val_loss: 574.9975 - val_mse: 574.9975 - val_mae: 15.3500 - 166s/epoch - 151ms/step

Epoch 9/25

1099/1099 - 169s - loss: 624.6741 - mse: 624.6741 - mae: 17.0023 - val_loss: 676.9548 - val_mse: 676.9548 - val_mae: 16.0798 - 169s/epoch - 154ms/step

Epoch 10/25

1099/1099 - 162s - loss: 608.9497 - mse: 608.9497 - mae: 16.6586 - val_loss: 559.1422 - val_mse: 559.1422 - val_mae: 16.2003 - 162s/epoch - 147ms/step

Epoch 11/25

1099/1099 - 159s - loss: 594.8096 - mse: 594.8096 - mae: 16.3499 - val_loss: 530.0433 - val_mse: 530.0433 - val_mae: 13.8758 - 159s/epoch - 145ms/step

Epoch 12/25

1099/1099 - 172s - loss: 583.2604 - mse: 583.2604 - mae: 16.0808 - val_loss: 568.7039 - val_mse: 568.7039 - val_mae: 14.2374 - 172s/epoch - 156ms/step

Epoch 13/25

1099/1099 - 161s - loss: 569.9501 - mse: 569.9501 - mae: 15.8216 - val_loss: 559.3549 - val_mse: 559.3549 - val_mae: 14.1040 - 161s/epoch - 147ms/step

Epoch 14/25

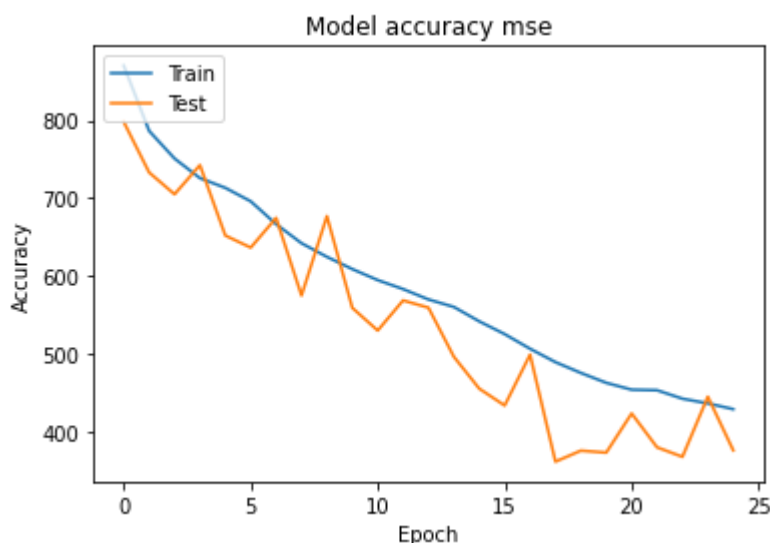
1099/1099 - 163s - loss: 560.2957 - mse: 560.2957 - mae: 15.5810 - val_loss: 496.3221 - val_mse: 496.3221 - val_mae: 13.1305 - 163s/epoch - 148ms/step

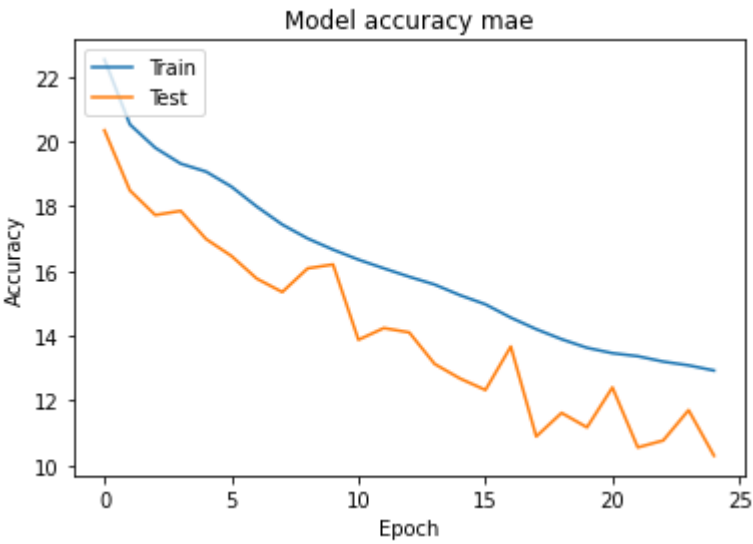
Epoch 15/25

1099/1099 - 160s - loss: 541.7988 - mse: 541.7988 - mae: 15.2525 - val_loss: 455.3860 - val_mse: 455.3860 - val_mae: 12.6816 - 160s/epoch - 146ms/step

Epoch 16/25

1099/1099 - 161s - loss: 525.4434 - mse: 525.4434 - mae: 14.9711 - val_loss: 433.7357 - val_mse: 433.7357 - val_mae: 12.3270 - 161s/epoch - 146ms/step
 Epoch 17/25
 1099/1099 - 161s - loss: 506.6176 - mse: 506.6176 - mae: 14.5604 - val_loss: 499.0404 - val_mse: 499.0404 - val_mae: 13.6676 - 161s/epoch - 147ms/step
 Epoch 18/25
 1099/1099 - 164s - loss: 489.4137 - mse: 489.4137 - mae: 14.2042 - val_loss: 361.6404 - val_mse: 361.6404 - val_mae: 10.8939 - 164s/epoch - 149ms/step
 Epoch 19/25
 1099/1099 - 161s - loss: 475.5882 - mse: 475.5882 - mae: 13.8938 - val_loss: 375.7463 - val_mse: 375.7463 - val_mae: 11.6199 - 161s/epoch - 147ms/step
 Epoch 20/25
 1099/1099 - 162s - loss: 462.8652 - mse: 462.8652 - mae: 13.6296 - val_loss: 373.2402 - val_mse: 373.2402 - val_mae: 11.1745 - 162s/epoch - 147ms/step
 Epoch 21/25
 1099/1099 - 163s - loss: 454.0345 - mse: 454.0345 - mae: 13.4640 - val_loss: 423.5359 - val_mse: 423.5359 - val_mae: 12.4048 - 163s/epoch - 148ms/step
 Epoch 22/25
 1099/1099 - 162s - loss: 453.3568 - mse: 453.3568 - mae: 13.3697 - val_loss: 380.0341 - val_mse: 380.0341 - val_mae: 10.5552 - 162s/epoch - 147ms/step
 Epoch 23/25
 1099/1099 - 161s - loss: 442.4781 - mse: 442.4781 - mae: 13.2035 - val_loss: 367.8569 - val_mse: 367.8569 - val_mae: 10.7696 - 161s/epoch - 147ms/step
 Epoch 24/25
 1099/1099 - 161s - loss: 436.4580 - mse: 436.4580 - mae: 13.0884 - val_loss: 445.0382 - val_mse: 445.0382 - val_mae: 11.7053 - 161s/epoch - 146ms/step
 Epoch 25/25
 1099/1099 - 162s - loss: 429.0586 - mse: 429.0586 - mae: 12.9287 - val_loss: 376.2139 - val_mse: 376.2139 - val_mae: 10.3018 - 162s/epoch - 148ms/step





In []:

```
antenna_num = 2
epochs = 25
filters=(64,32,16)
lr = 0.001
opt = Adam(learning_rate=lr)
regress=True

model = create_2d_cnn(100, 4, 1, filters, regress, "relu")
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x=x_train_phase, y=y_train,
    validation_data=( x_test_phase, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Epoch 1/25

1099/1099 - 102s - loss: 1011.1041 - mse: 1011.1041 - mae: 25.8062 - val_loss: 792.1529 - val_mse: 792.1529 - val_mae: 19.7709 - 102s/epoch - 93ms/step

Epoch 2/25

1099/1099 - 99s - loss: 811.7446 - mse: 811.7446 - mae: 20.9664 - val_loss: 792.1965 - val_mse: 792.1965 - val_mae: 19.8763 - 99s/epoch - 90ms/step

Epoch 3/25

1099/1099 - 99s - loss: 788.4951 - mse: 788.4951 - mae: 20.5958 - val_loss: 735.8916 - val_mse: 735.8916 - val_mae: 18.5863 - 99s/epoch - 90ms/step

Epoch 4/25

1099/1099 - 100s - loss: 773.4467 - mse: 773.4467 - mae: 20.2689 - val_loss: 727.9021 - val_mse: 727.9021 - val_mae: 18.3658 - 100s/epoch - 91ms/step

Epoch 5/25

1099/1099 - 99s - loss: 760.7055 - mse: 760.7055 - mae: 20.0006 - val_loss: 717.4006 - val_mse: 717.4006 - val_mae: 18.3424 - 99s/epoch - 90ms/step

Epoch 6/25

1099/1099 - 99s - loss: 757.0266 - mse: 757.0266 - mae: 19.8885 - val_loss: 712.7858 - val_mse: 712.7858 - val_mae: 18.3599 - 99s/epoch - 90ms/step

Epoch 7/25

1099/1099 - 99s - loss: 755.1722 - mse: 755.1722 - mae: 19.8868 - val_loss: 762.8583 - val_mse: 762.8583 - val_mae: 18.8659 - 99s/epoch - 91ms/step

Epoch 8/25

1099/1099 - 100s - loss: 751.6990 - mse: 751.6990 - mae: 19.7892 - val_loss: 707.0729 - val_mse: 707.0729 - val_mae: 18.2075 - 100s/epoch - 91ms/step

Epoch 9/25

1099/1099 - 99s - loss: 744.2941 - mse: 744.2941 - mae: 19.6084 - val_loss: 743.4955 - val_mse: 743.4955 - val_mae: 18.1103 - 99s/epoch - 90ms/step

Epoch 10/25

1099/1099 - 100s - loss: 742.4045 - mse: 742.4045 - mae: 19.5879 - val_loss: 734.0561 - val_mse: 734.0561 - val_mae: 18.4975 - 100s/epoch - 91ms/step

Epoch 11/25

1099/1099 - 99s - loss: 740.3631 - mse: 740.3631 - mae: 19.5445 - val_loss: 706.3829 - val_mse: 706.3829 - val_mae: 17.6604 - 99s/epoch - 90ms/step

Epoch 12/25

1099/1099 - 99s - loss: 739.2933 - mse: 739.2933 - mae: 19.5020 - val_loss: 721.6161 - val_mse: 721.6161 - val_mae: 18.0193 - 99s/epoch - 90ms/step

Epoch 13/25

1099/1099 - 99s - loss: 752.1691 - mse: 752.1691 - mae: 19.7024 - val_loss: 718.0164 - val_mse: 718.0164 - val_mae: 19.2835 - 99s/epoch - 90ms/step

Epoch 14/25

1099/1099 - 100s - loss: 739.1594 - mse: 739.1594 - mae: 19.4765 - val_loss: 745.6871 - val_mse: 745.6871 - val_mae: 18.9125 - 100s/epoch - 91ms/step

Epoch 15/25

1099/1099 - 99s - loss: 735.6421 - mse: 735.6421 - mae: 19.4284 - val_loss: 719.6741 - val_mse: 719.6741 - val_mae: 18.6305 - 99s/epoch - 90ms/step

Epoch 16/25

1099/1099 - 98s - loss: 734.7121 - mse: 734.7121 - mae: 19.4134 - val_loss: 776.7823 - val_mse: 776.7823 - val_mae: 19.2667 - 98s/epoch - 89ms/step

Epoch 17/25

1099/1099 - 99s - loss: 752.7654 - mse: 752.7654 - mae: 19.6912 - val_loss: 714.2552 - val_mse: 714.2552 - val_mae: 17.7103 - 99s/epoch - 90ms/step

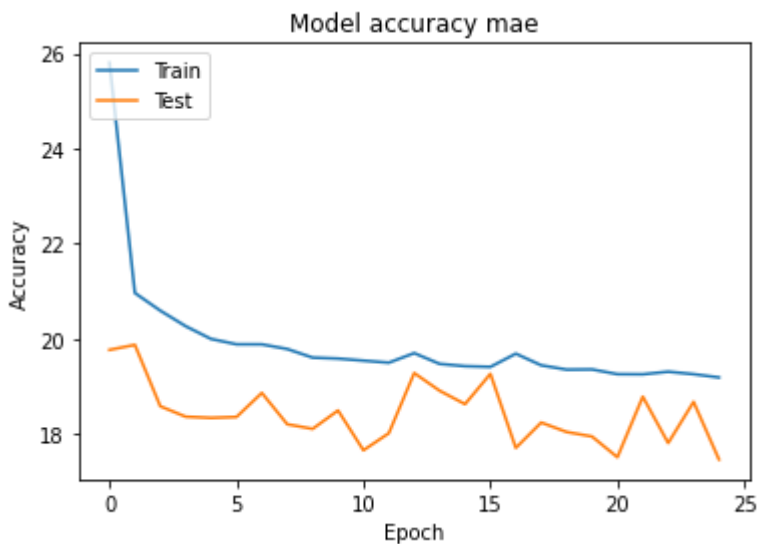
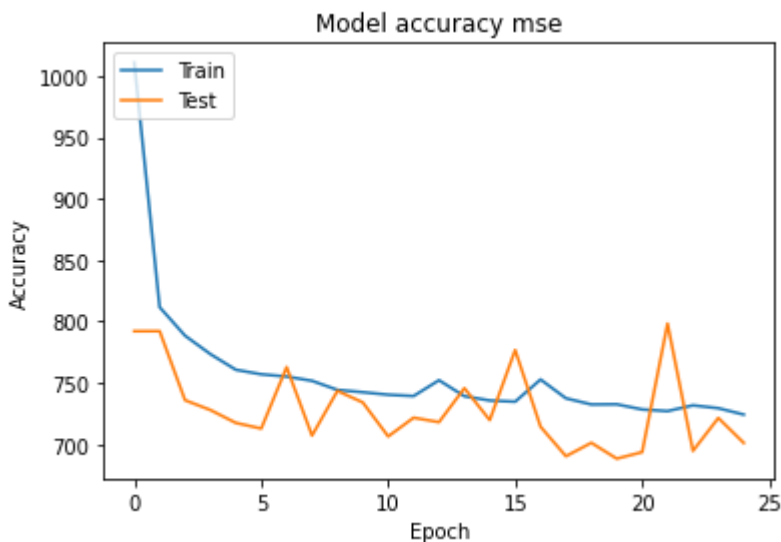
Epoch 18/25

1099/1099 - 99s - loss: 737.4454 - mse: 737.4454 - mae: 19.4469 - val_loss: 690.2399 - val_mse: 690.2399 - val_mae: 18.2438 - 99s/epoch - 90ms/step

Epoch 19/25

1099/1099 - 99s - loss: 732.4239 - mse: 732.4239 - mae: 19.3561 - val_loss:

s: 701.1613 - val_mse: 701.1613 - val_mae: 18.0453 - 99s/epoch - 90ms/step
Epoch 20/25
1099/1099 - 100s - loss: 732.5556 - mse: 732.5556 - mae: 19.3604 - val_loss: 688.2559 - val_mse: 688.2559 - val_mae: 17.9503 - 100s/epoch - 91ms/step
Epoch 21/25
1099/1099 - 100s - loss: 728.3617 - mse: 728.3617 - mae: 19.2606 - val_loss: 693.5634 - val_mse: 693.5634 - val_mae: 17.5144 - 100s/epoch - 91ms/step
Epoch 22/25
1099/1099 - 99s - loss: 727.0125 - mse: 727.0125 - mae: 19.2576 - val_loss: 798.3551 - val_mse: 798.3551 - val_mae: 18.7867 - 99s/epoch - 90ms/step
Epoch 23/25
1099/1099 - 100s - loss: 731.7050 - mse: 731.7050 - mae: 19.3123 - val_loss: 694.5927 - val_mse: 694.5927 - val_mae: 17.8125 - 100s/epoch - 91ms/step
Epoch 24/25
1099/1099 - 100s - loss: 729.3707 - mse: 729.3707 - mae: 19.2601 - val_loss: 721.3913 - val_mse: 721.3913 - val_mae: 18.6778 - 100s/epoch - 91ms/step
Epoch 25/25
1099/1099 - 100s - loss: 724.1766 - mse: 724.1766 - mae: 19.1912 - val_loss: 701.1145 - val_mse: 701.1145 - val_mae: 17.4670 - 100s/epoch - 91ms/step



In []:

```
antenna_num = 2
epochs = 25
filters=(64,32,16)
lr = 0.001
opt = Adam(learning_rate=lr)
regress=True

model = create_2d_cnn(100, 4, 1, filters, regress, "relu")

model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x=x_train_magnitude, y=y_train,
    validation_data=(x_test_magnitude, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```


Epoch 1/25

1099/1099 - 101s - loss: 892.0627 - mse: 892.0627 - mae: 23.2480 - val_loss: 806.5480 - val_mse: 806.5480 - val_mae: 21.0223 - 101s/epoch - 92ms/step

Epoch 2/25

1099/1099 - 102s - loss: 817.5516 - mse: 817.5516 - mae: 21.4317 - val_loss: 795.7069 - val_mse: 795.7069 - val_mae: 20.9200 - 102s/epoch - 93ms/step

Epoch 3/25

1099/1099 - 102s - loss: 801.6130 - mse: 801.6130 - mae: 21.1763 - val_loss: 755.3731 - val_mse: 755.3731 - val_mae: 20.0149 - 102s/epoch - 93ms/step

Epoch 4/25

1099/1099 - 101s - loss: 779.4277 - mse: 779.4277 - mae: 20.7689 - val_loss: 717.4008 - val_mse: 717.4008 - val_mae: 18.5678 - 101s/epoch - 92ms/step

Epoch 5/25

1099/1099 - 100s - loss: 762.0817 - mse: 762.0817 - mae: 20.3970 - val_loss: 705.8080 - val_mse: 705.8080 - val_mae: 18.6564 - 100s/epoch - 91ms/step

Epoch 6/25

1099/1099 - 99s - loss: 748.8035 - mse: 748.8035 - mae: 20.1588 - val_loss: 693.0465 - val_mse: 693.0465 - val_mae: 18.0041 - 99s/epoch - 91ms/step

Epoch 7/25

1099/1099 - 100s - loss: 739.8503 - mse: 739.8503 - mae: 19.9384 - val_loss: 680.6411 - val_mse: 680.6411 - val_mae: 18.0983 - 100s/epoch - 91ms/step

Epoch 8/25

1099/1099 - 101s - loss: 733.2516 - mse: 733.2516 - mae: 19.7782 - val_loss: 664.0025 - val_mse: 664.0025 - val_mae: 17.6752 - 101s/epoch - 91ms/step

Epoch 9/25

1099/1099 - 102s - loss: 719.1041 - mse: 719.1041 - mae: 19.4737 - val_loss: 646.8347 - val_mse: 646.8347 - val_mae: 17.2760 - 102s/epoch - 93ms/step

Epoch 10/25

1099/1099 - 102s - loss: 709.9136 - mse: 709.9136 - mae: 19.3226 - val_loss: 642.0100 - val_mse: 642.0100 - val_mae: 17.2213 - 102s/epoch - 93ms/step

Epoch 11/25

1099/1099 - 103s - loss: 697.1243 - mse: 697.1243 - mae: 19.0828 - val_loss: 620.6154 - val_mse: 620.6154 - val_mae: 16.4995 - 103s/epoch - 94ms/step

Epoch 12/25

1099/1099 - 103s - loss: 683.6797 - mse: 683.6797 - mae: 18.8338 - val_loss: 600.2341 - val_mse: 600.2341 - val_mae: 16.1111 - 103s/epoch - 94ms/step

Epoch 13/25

1099/1099 - 102s - loss: 691.8763 - mse: 691.8763 - mae: 18.9342 - val_loss: 614.6382 - val_mse: 614.6382 - val_mae: 16.3807 - 102s/epoch - 92ms/step

Epoch 14/25

1099/1099 - 100s - loss: 657.1886 - mse: 657.1886 - mae: 18.2805 - val_loss: 588.7519 - val_mse: 588.7519 - val_mae: 15.8530 - 100s/epoch - 91ms/step

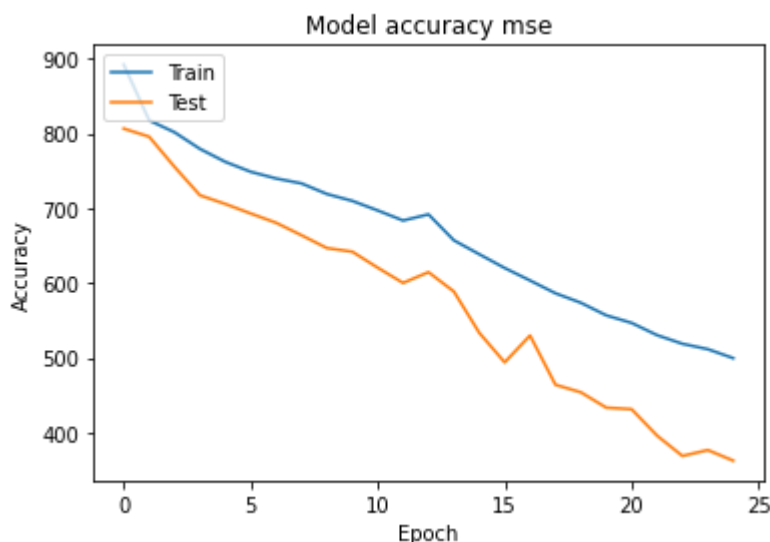
Epoch 15/25

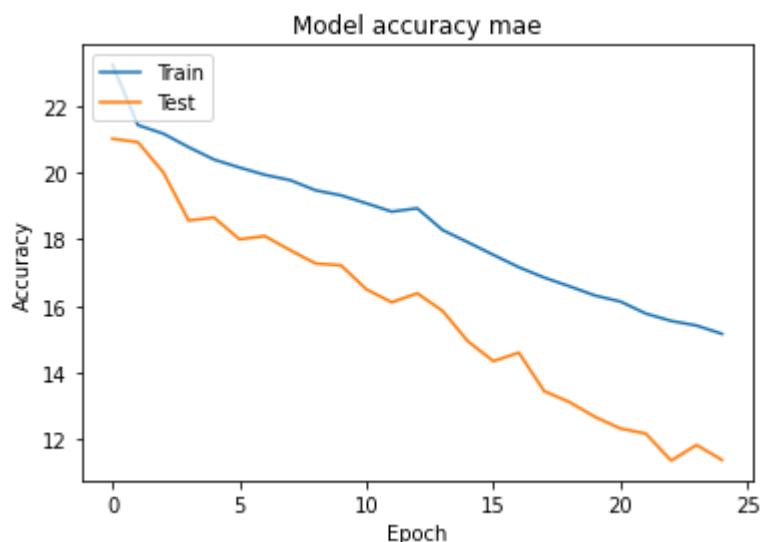
1099/1099 - 100s - loss: 638.5999 - mse: 638.5999 - mae: 17.9119 - val_loss: 533.5676 - val_mse: 533.5676 - val_mae: 14.9377 - 100s/epoch - 91ms/step

Epoch 16/25

1099/1099 - 100s - loss: 620.2070 - mse: 620.2070 - mae: 17.5356 - val_loss:

s: 494.1069 - val_mse: 494.1069 - val_mae: 14.3448 - 100s/epoch - 91ms/step
Epoch 17/25
1099/1099 - 100s - loss: 603.5022 - mse: 603.5022 - mae: 17.1649 - val_loss: 529.9139 - val_mse: 529.9139 - val_mae: 14.5983 - 100s/epoch - 91ms/step
Epoch 18/25
1099/1099 - 100s - loss: 586.4215 - mse: 586.4215 - mae: 16.8535 - val_loss: 464.1360 - val_mse: 464.1360 - val_mae: 13.4438 - 100s/epoch - 91ms/step
Epoch 19/25
1099/1099 - 100s - loss: 573.7258 - mse: 573.7258 - mae: 16.5905 - val_loss: 454.0565 - val_mse: 454.0565 - val_mae: 13.1131 - 100s/epoch - 91ms/step
Epoch 20/25
1099/1099 - 99s - loss: 556.9063 - mse: 556.9063 - mae: 16.3151 - val_loss: 433.5365 - val_mse: 433.5365 - val_mae: 12.6708 - 99s/epoch - 90ms/step
Epoch 21/25
1099/1099 - 100s - loss: 546.7626 - mse: 546.7626 - mae: 16.1347 - val_loss: 431.4627 - val_mse: 431.4627 - val_mae: 12.3216 - 100s/epoch - 91ms/step
Epoch 22/25
1099/1099 - 100s - loss: 530.4498 - mse: 530.4498 - mae: 15.7736 - val_loss: 396.1434 - val_mse: 396.1434 - val_mae: 12.1695 - 100s/epoch - 91ms/step
Epoch 23/25
1099/1099 - 99s - loss: 518.8772 - mse: 518.8772 - mae: 15.5517 - val_loss: 368.9839 - val_mse: 368.9839 - val_mae: 11.3575 - 99s/epoch - 90ms/step
Epoch 24/25
1099/1099 - 100s - loss: 511.6860 - mse: 511.6860 - mae: 15.4138 - val_loss: 376.8333 - val_mse: 376.8333 - val_mae: 11.8295 - 100s/epoch - 91ms/step
Epoch 25/25
1099/1099 - 100s - loss: 499.6666 - mse: 499.6666 - mae: 15.1645 - val_loss: 362.7004 - val_mse: 362.7004 - val_mae: 11.3777 - 100s/epoch - 91ms/step





2-by-2 antenna array with PCA

In []:

```
magnitude = pd.read_csv('/content/drive/MyDrive/train_magnitude.csv', header=None).to_numpy()
output_data = pd.read_csv('/content/drive/MyDrive/train_outputs.csv', header=None).to_numpy()
phase = pd.read_csv('/content/drive/MyDrive/train_phase.csv', header=None).to_numpy()

data = load_data(phase, magnitude, output_data, antenna_num)

phase_data = data[0]
magnitude_data = data[1]
output_data = data[2]

reduced_data = perform_dimensionality_reduction(phase_data, magnitude_data)
phase_data = reduced_data[0]
magnitude_data = reduced_data[1]

data_split = split_test_train(phase_data, magnitude_data, output_data, 0.4)
x_train_magnitude = data_split[0]
x_test_magnitude = data_split[1]
x_train_phase = data_split[2]
x_test_phase = data_split[3]
y_train = data_split[4][:,0:2]
y_test = data_split[5][:,0:2]

lr = 0.001
epochs = 100
opt = Adam(learning_rate=lr)
```

In []:

```
print("Combined phase and magnitude MLP")

layers = (40,10)
shape = (40,)
magnitude = create_mlp(shape, layers, False, "relu")
phase = create_mlp(shape, layers, False, "relu")

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x=[x_train_magnitude, x_train_phase], y=y_train,
    validation_data=(x_test_magnitude, x_test_phase), y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Combined phase and magnitude MLP

Epoch 1/100

1099/1099 - 3s - loss: 1220.4243 - mse: 1220.4243 - mae: 30.2614 - val_loss: 1218.6901 - val_mse: 1218.6901 - val_mae: 30.2204 - 3s/epoch - 3ms/step

Epoch 2/100

1099/1099 - 2s - loss: 1219.5498 - mse: 1219.5498 - mae: 30.2485 - val_loss: 1217.5602 - val_mse: 1217.5602 - val_mae: 30.2034 - 2s/epoch - 2ms/step

Epoch 3/100

1099/1099 - 2s - loss: 1218.3538 - mse: 1218.3538 - mae: 30.2312 - val_loss: 1216.1229 - val_mse: 1216.1229 - val_mae: 30.1812 - 2s/epoch - 2ms/step

Epoch 4/100

1099/1099 - 2s - loss: 1216.3759 - mse: 1216.3759 - mae: 30.1987 - val_loss: 1212.0793 - val_mse: 1212.0793 - val_mae: 30.1212 - 2s/epoch - 2ms/step

Epoch 5/100

1099/1099 - 3s - loss: 1211.3856 - mse: 1211.3856 - mae: 30.1137 - val_loss: 1201.4552 - val_mse: 1201.4552 - val_mae: 29.9640 - 3s/epoch - 2ms/step

Epoch 6/100

1099/1099 - 2s - loss: 1203.0907 - mse: 1203.0907 - mae: 29.9589 - val_loss: 1180.0905 - val_mse: 1180.0905 - val_mae: 29.6470 - 2s/epoch - 2ms/step

Epoch 7/100

1099/1099 - 2s - loss: 1183.0438 - mse: 1183.0438 - mae: 29.5954 - val_loss: 1133.9657 - val_mse: 1133.9657 - val_mae: 28.9063 - 2s/epoch - 2ms/step

Epoch 8/100

1099/1099 - 2s - loss: 1150.2987 - mse: 1150.2987 - mae: 28.9725 - val_loss: 1074.4005 - val_mse: 1074.4005 - val_mae: 27.7981 - 2s/epoch - 2ms/step

Epoch 9/100

1099/1099 - 2s - loss: 1105.2329 - mse: 1105.2329 - mae: 28.0446 - val_loss: 1007.2913 - val_mse: 1007.2913 - val_mae: 26.4001 - 2s/epoch - 2ms/step

Epoch 10/100

1099/1099 - 3s - loss: 1059.8762 - mse: 1059.8762 - mae: 27.1014 - val_loss: 960.5413 - val_mse: 960.5413 - val_mae: 25.3143 - 3s/epoch - 2ms/step

Epoch 11/100

1099/1099 - 2s - loss: 1024.9821 - mse: 1024.9821 - mae: 26.3294 - val_loss: 939.5178 - val_mse: 939.5178 - val_mae: 24.7647 - 2s/epoch - 2ms/step

Epoch 12/100

1099/1099 - 2s - loss: 997.1172 - mse: 997.1172 - mae: 25.7504 - val_loss: 921.7731 - val_mse: 921.7731 - val_mae: 24.3200 - 2s/epoch - 2ms/step

Epoch 13/100

1099/1099 - 2s - loss: 978.6317 - mse: 978.6317 - mae: 25.3546 - val_loss: 901.4366 - val_mse: 901.4366 - val_mae: 23.7911 - 2s/epoch - 2ms/step

Epoch 14/100

1099/1099 - 2s - loss: 966.4019 - mse: 966.4019 - mae: 25.0437 - val_loss: 900.4521 - val_mse: 900.4521 - val_mae: 23.8084 - 2s/epoch - 2ms/step

Epoch 15/100

1099/1099 - 2s - loss: 956.9122 - mse: 956.9122 - mae: 24.8655 - val_loss: 892.4971 - val_mse: 892.4971 - val_mae: 23.5818 - 2s/epoch - 2ms/step

Epoch 16/100

1099/1099 - 2s - loss: 947.3326 - mse: 947.3326 - mae: 24.6638 - val_loss: 883.2513 - val_mse: 883.2513 - val_mae: 23.3570 - 2s/epoch - 2ms/step

Epoch 17/100

1099/1099 - 2s - loss: 940.8312 - mse: 940.8312 - mae: 24.5149 - val_loss: 879.7424 - val_mse: 879.7424 - val_mae: 23.2371 - 2s/epoch - 2ms/step

Epoch 18/100

1099/1099 - 2s - loss: 937.8395 - mse: 937.8395 - mae: 24.4475 - val_loss: 876.2108 - val_mse: 876.2108 - val_mae: 23.1702 - 2s/epoch - 2ms/step

Epoch 19/100

1099/1099 - 2s - loss: 930.8911 - mse: 930.8911 - mae: 24.3379 - val_loss: 874.3079 - val_mse: 874.3079 - val_mae: 23.1674 - 2s/epoch - 2ms/step

Epoch 20/100

1099/1099 - 2s - loss: 932.2515 - mse: 932.2515 - mae: 24.3381 - val_loss: 872.4382 - val_mse: 872.4382 - val_mae: 23.0685 - 2s/epoch - 2ms/step

Epoch 21/100

1099/1099 - 2s - loss: 927.5084 - mse: 927.5084 - mae: 24.2336 - val_loss: 872.6052 - val_mse: 872.6052 - val_mae: 23.0673 - 2s/epoch - 2ms/step

Epoch 22/100

1099/1099 - 2s - loss: 923.7978 - mse: 923.7978 - mae: 24.1604 - val_loss: 870.8288 - val_mse: 870.8288 - val_mae: 23.0246 - 2s/epoch - 2ms/step

Epoch 23/100

1099/1099 - 2s - loss: 924.0066 - mse: 924.0066 - mae: 24.1657 - val_loss: 864.4640 - val_mse: 864.4640 - val_mae: 22.8287 - 2s/epoch - 2ms/step

Epoch 24/100

1099/1099 - 2s - loss: 920.3025 - mse: 920.3025 - mae: 24.0708 - val_loss: 862.0488 - val_mse: 862.0488 - val_mae: 22.7913 - 2s/epoch - 2ms/step

Epoch 25/100

1099/1099 - 2s - loss: 919.6486 - mse: 919.6486 - mae: 24.0679 - val_loss: 861.4903 - val_mse: 861.4903 - val_mae: 22.8415 - 2s/epoch - 2ms/step

Epoch 26/100

1099/1099 - 2s - loss: 915.4541 - mse: 915.4541 - mae: 23.9860 - val_loss: 862.7271 - val_mse: 862.7271 - val_mae: 22.8562 - 2s/epoch - 2ms/step

Epoch 27/100

1099/1099 - 2s - loss: 915.5226 - mse: 915.5226 - mae: 23.9846 - val_loss: 860.4774 - val_mse: 860.4774 - val_mae: 22.7838 - 2s/epoch - 2ms/step

Epoch 28/100

1099/1099 - 2s - loss: 912.9908 - mse: 912.9908 - mae: 23.9373 - val_loss: 861.1306 - val_mse: 861.1306 - val_mae: 22.8036 - 2s/epoch - 2ms/step

Epoch 29/100

1099/1099 - 2s - loss: 911.9661 - mse: 911.9661 - mae: 23.9119 - val_loss: 857.4001 - val_mse: 857.4001 - val_mae: 22.7199 - 2s/epoch - 2ms/step

Epoch 30/100

1099/1099 - 2s - loss: 911.2148 - mse: 911.2148 - mae: 23.9167 - val_loss: 866.4727 - val_mse: 866.4727 - val_mae: 22.9567 - 2s/epoch - 2ms/step

Epoch 31/100

1099/1099 - 2s - loss: 910.2256 - mse: 910.2256 - mae: 23.8653 - val_loss: 854.3936 - val_mse: 854.3936 - val_mae: 22.6536 - 2s/epoch - 2ms/step

Epoch 32/100

1099/1099 - 2s - loss: 905.3555 - mse: 905.3555 - mae: 23.7926 - val_loss: 855.5649 - val_mse: 855.5649 - val_mae: 22.6952 - 2s/epoch - 2ms/step

Epoch 33/100

1099/1099 - 2s - loss: 905.7891 - mse: 905.7891 - mae: 23.7930 - val_loss: 852.2278 - val_mse: 852.2278 - val_mae: 22.6071 - 2s/epoch - 2ms/step

Epoch 34/100

1099/1099 - 2s - loss: 905.3749 - mse: 905.3749 - mae: 23.7856 - val_loss: 854.0458 - val_mse: 854.0458 - val_mae: 22.6639 - 2s/epoch - 2ms/step

Epoch 35/100

1099/1099 - 2s - loss: 906.0281 - mse: 906.0281 - mae: 23.7922 - val_loss: 852.1747 - val_mse: 852.1747 - val_mae: 22.5698 - 2s/epoch - 2ms/step

Epoch 36/100

1099/1099 - 2s - loss: 902.2498 - mse: 902.2498 - mae: 23.7175 - val_loss: 852.4038 - val_mse: 852.4038 - val_mae: 22.5681 - 2s/epoch - 2ms/step

Epoch 37/100

1099/1099 - 2s - loss: 903.5773 - mse: 903.5773 - mae: 23.7266 - val_loss: 855.9458 - val_mse: 855.9458 - val_mae: 22.6986 - 2s/epoch - 2ms/step

Epoch 38/100

1099/1099 - 2s - loss: 903.1401 - mse: 903.1401 - mae: 23.7211 - val_loss: 851.9169 - val_mse: 851.9169 - val_mae: 22.5664 - 2s/epoch - 2ms/step

Epoch 39/100

1099/1099 - 2s - loss: 900.2139 - mse: 900.2139 - mae: 23.6814 - val_loss: 853.5440 - val_mse: 853.5440 - val_mae: 22.6150 - 2s/epoch - 2ms/step

Epoch 40/100

1099/1099 - 2s - loss: 898.5853 - mse: 898.5853 - mae: 23.6178 - val_loss: 850.5106 - val_mse: 850.5106 - val_mae: 22.5759 - 2s/epoch - 2ms/step

Epoch 41/100

1099/1099 - 2s - loss: 899.5221 - mse: 899.5221 - mae: 23.6666 - val_loss: 855.4748 - val_mse: 855.4748 - val_mae: 22.7116 - 2s/epoch - 2ms/step
Epoch 42/100
1099/1099 - 2s - loss: 896.8516 - mse: 896.8516 - mae: 23.6132 - val_loss: 849.3291 - val_mse: 849.3291 - val_mae: 22.5120 - 2s/epoch - 2ms/step
Epoch 43/100
1099/1099 - 2s - loss: 895.6896 - mse: 895.6896 - mae: 23.5973 - val_loss: 846.8271 - val_mse: 846.8271 - val_mae: 22.4439 - 2s/epoch - 2ms/step
Epoch 44/100
1099/1099 - 2s - loss: 896.1092 - mse: 896.1092 - mae: 23.5604 - val_loss: 847.9788 - val_mse: 847.9788 - val_mae: 22.5058 - 2s/epoch - 2ms/step
Epoch 45/100
1099/1099 - 2s - loss: 894.6590 - mse: 894.6590 - mae: 23.5552 - val_loss: 845.5579 - val_mse: 845.5579 - val_mae: 22.4232 - 2s/epoch - 2ms/step
Epoch 46/100
1099/1099 - 2s - loss: 893.5120 - mse: 893.5120 - mae: 23.5379 - val_loss: 850.1948 - val_mse: 850.1948 - val_mae: 22.5067 - 2s/epoch - 2ms/step
Epoch 47/100
1099/1099 - 2s - loss: 893.0414 - mse: 893.0414 - mae: 23.5206 - val_loss: 843.8821 - val_mse: 843.8821 - val_mae: 22.3679 - 2s/epoch - 2ms/step
Epoch 48/100
1099/1099 - 2s - loss: 893.4833 - mse: 893.4833 - mae: 23.5180 - val_loss: 842.3267 - val_mse: 842.3267 - val_mae: 22.3304 - 2s/epoch - 2ms/step
Epoch 49/100
1099/1099 - 2s - loss: 891.8444 - mse: 891.8444 - mae: 23.5035 - val_loss: 844.8317 - val_mse: 844.8317 - val_mae: 22.4216 - 2s/epoch - 2ms/step
Epoch 50/100
1099/1099 - 2s - loss: 890.5070 - mse: 890.5070 - mae: 23.4600 - val_loss: 842.1860 - val_mse: 842.1860 - val_mae: 22.3496 - 2s/epoch - 2ms/step
Epoch 51/100
1099/1099 - 2s - loss: 889.8328 - mse: 889.8328 - mae: 23.4482 - val_loss: 842.8445 - val_mse: 842.8445 - val_mae: 22.3218 - 2s/epoch - 2ms/step
Epoch 52/100
1099/1099 - 2s - loss: 888.8114 - mse: 888.8114 - mae: 23.4077 - val_loss: 843.7339 - val_mse: 843.7339 - val_mae: 22.3414 - 2s/epoch - 2ms/step
Epoch 53/100
1099/1099 - 2s - loss: 891.3886 - mse: 891.3886 - mae: 23.4567 - val_loss: 847.4427 - val_mse: 847.4427 - val_mae: 22.5003 - 2s/epoch - 2ms/step
Epoch 54/100
1099/1099 - 2s - loss: 890.2655 - mse: 890.2655 - mae: 23.4408 - val_loss: 845.6577 - val_mse: 845.6577 - val_mae: 22.4478 - 2s/epoch - 2ms/step
Epoch 55/100
1099/1099 - 2s - loss: 887.1660 - mse: 887.1660 - mae: 23.3672 - val_loss: 840.6286 - val_mse: 840.6286 - val_mae: 22.2745 - 2s/epoch - 2ms/step
Epoch 56/100
1099/1099 - 2s - loss: 886.5303 - mse: 886.5303 - mae: 23.3771 - val_loss: 843.8921 - val_mse: 843.8921 - val_mae: 22.3486 - 2s/epoch - 2ms/step
Epoch 57/100
1099/1099 - 2s - loss: 887.1223 - mse: 887.1223 - mae: 23.3766 - val_loss: 840.6371 - val_mse: 840.6371 - val_mae: 22.2726 - 2s/epoch - 2ms/step
Epoch 58/100
1099/1099 - 2s - loss: 885.0471 - mse: 885.0471 - mae: 23.3438 - val_loss: 841.6624 - val_mse: 841.6624 - val_mae: 22.3377 - 2s/epoch - 2ms/step
Epoch 59/100
1099/1099 - 2s - loss: 885.6667 - mse: 885.6667 - mae: 23.3452 - val_loss: 845.5714 - val_mse: 845.5714 - val_mae: 22.4549 - 2s/epoch - 2ms/step
Epoch 60/100
1099/1099 - 2s - loss: 885.0555 - mse: 885.0555 - mae: 23.3441 - val_loss: 841.5771 - val_mse: 841.5771 - val_mae: 22.3359 - 2s/epoch - 2ms/step
Epoch 61/100
1099/1099 - 2s - loss: 883.2724 - mse: 883.2724 - mae: 23.2866 - val_loss:

840.4389 - val_mse: 840.4389 - val_mae: 22.2838 - 2s/epoch - 2ms/step
Epoch 62/100
1099/1099 - 2s - loss: 883.2661 - mse: 883.2661 - mae: 23.2910 - val_loss:
837.9756 - val_mse: 837.9756 - val_mae: 22.2197 - 2s/epoch - 2ms/step
Epoch 63/100
1099/1099 - 2s - loss: 883.1022 - mse: 883.1022 - mae: 23.3027 - val_loss:
839.0566 - val_mse: 839.0566 - val_mae: 22.2411 - 2s/epoch - 2ms/step
Epoch 64/100
1099/1099 - 2s - loss: 881.7102 - mse: 881.7102 - mae: 23.2509 - val_loss:
836.3455 - val_mse: 836.3455 - val_mae: 22.1963 - 2s/epoch - 2ms/step
Epoch 65/100
1099/1099 - 2s - loss: 882.2518 - mse: 882.2518 - mae: 23.2624 - val_loss:
838.2920 - val_mse: 838.2920 - val_mae: 22.2337 - 2s/epoch - 2ms/step
Epoch 66/100
1099/1099 - 2s - loss: 881.8683 - mse: 881.8683 - mae: 23.2494 - val_loss:
836.5823 - val_mse: 836.5823 - val_mae: 22.1236 - 2s/epoch - 2ms/step
Epoch 67/100
1099/1099 - 2s - loss: 880.7504 - mse: 880.7504 - mae: 23.2284 - val_loss:
837.4302 - val_mse: 837.4302 - val_mae: 22.1998 - 2s/epoch - 2ms/step
Epoch 68/100
1099/1099 - 2s - loss: 881.2985 - mse: 881.2985 - mae: 23.2383 - val_loss:
837.5684 - val_mse: 837.5684 - val_mae: 22.2026 - 2s/epoch - 2ms/step
Epoch 69/100
1099/1099 - 3s - loss: 882.4903 - mse: 882.4903 - mae: 23.2651 - val_loss:
842.4023 - val_mse: 842.4023 - val_mae: 22.3132 - 3s/epoch - 2ms/step
Epoch 70/100
1099/1099 - 3s - loss: 880.5797 - mse: 880.5797 - mae: 23.2179 - val_loss:
835.1270 - val_mse: 835.1270 - val_mae: 22.0779 - 3s/epoch - 2ms/step
Epoch 71/100
1099/1099 - 2s - loss: 880.0410 - mse: 880.0410 - mae: 23.1882 - val_loss:
837.8970 - val_mse: 837.8970 - val_mae: 22.1988 - 2s/epoch - 2ms/step
Epoch 72/100
1099/1099 - 2s - loss: 881.9332 - mse: 881.9332 - mae: 23.2406 - val_loss:
838.7895 - val_mse: 838.7895 - val_mae: 22.2512 - 2s/epoch - 2ms/step
Epoch 73/100
1099/1099 - 2s - loss: 878.3668 - mse: 878.3668 - mae: 23.1644 - val_loss:
838.5954 - val_mse: 838.5954 - val_mae: 22.1999 - 2s/epoch - 2ms/step
Epoch 74/100
1099/1099 - 3s - loss: 880.8215 - mse: 880.8215 - mae: 23.2086 - val_loss:
838.5256 - val_mse: 838.5256 - val_mae: 22.1712 - 3s/epoch - 2ms/step
Epoch 75/100
1099/1099 - 2s - loss: 877.3016 - mse: 877.3016 - mae: 23.1456 - val_loss:
836.8365 - val_mse: 836.8365 - val_mae: 22.1742 - 2s/epoch - 2ms/step
Epoch 76/100
1099/1099 - 2s - loss: 877.9227 - mse: 877.9227 - mae: 23.1597 - val_loss:
836.3517 - val_mse: 836.3517 - val_mae: 22.1001 - 2s/epoch - 2ms/step
Epoch 77/100
1099/1099 - 2s - loss: 876.7645 - mse: 876.7645 - mae: 23.1168 - val_loss:
835.5219 - val_mse: 835.5219 - val_mae: 22.1315 - 2s/epoch - 2ms/step
Epoch 78/100
1099/1099 - 2s - loss: 876.7520 - mse: 876.7520 - mae: 23.1204 - val_loss:
836.9891 - val_mse: 836.9891 - val_mae: 22.1611 - 2s/epoch - 2ms/step
Epoch 79/100
1099/1099 - 2s - loss: 876.9647 - mse: 876.9647 - mae: 23.1389 - val_loss:
835.7537 - val_mse: 835.7537 - val_mae: 22.1550 - 2s/epoch - 2ms/step
Epoch 80/100
1099/1099 - 2s - loss: 875.7762 - mse: 875.7762 - mae: 23.1200 - val_loss:
835.1599 - val_mse: 835.1599 - val_mae: 22.0801 - 2s/epoch - 2ms/step
Epoch 81/100
1099/1099 - 2s - loss: 875.2734 - mse: 875.2734 - mae: 23.0676 - val_loss:
833.1453 - val_mse: 833.1453 - val_mae: 22.0478 - 2s/epoch - 2ms/step

Epoch 82/100

1099/1099 - 2s - loss: 875.1000 - mse: 875.1000 - mae: 23.0520 - val_loss: 834.2982 - val_mse: 834.2982 - val_mae: 22.0610 - 2s/epoch - 2ms/step

Epoch 83/100

1099/1099 - 2s - loss: 874.3994 - mse: 874.3994 - mae: 23.0536 - val_loss: 834.6977 - val_mse: 834.6977 - val_mae: 22.0408 - 2s/epoch - 2ms/step

Epoch 84/100

1099/1099 - 2s - loss: 873.3902 - mse: 873.3902 - mae: 23.0270 - val_loss: 830.2946 - val_mse: 830.2946 - val_mae: 21.9512 - 2s/epoch - 2ms/step

Epoch 85/100

1099/1099 - 2s - loss: 870.6918 - mse: 870.6918 - mae: 22.9854 - val_loss: 836.4169 - val_mse: 836.4169 - val_mae: 22.1163 - 2s/epoch - 2ms/step

Epoch 86/100

1099/1099 - 2s - loss: 872.7094 - mse: 872.7094 - mae: 23.0029 - val_loss: 833.0557 - val_mse: 833.0557 - val_mae: 22.0717 - 2s/epoch - 2ms/step

Epoch 87/100

1099/1099 - 3s - loss: 872.6668 - mse: 872.6668 - mae: 23.0032 - val_loss: 833.4969 - val_mse: 833.4969 - val_mae: 22.0262 - 3s/epoch - 2ms/step

Epoch 88/100

1099/1099 - 2s - loss: 870.3195 - mse: 870.3195 - mae: 22.9484 - val_loss: 831.5313 - val_mse: 831.5313 - val_mae: 21.9756 - 2s/epoch - 2ms/step

Epoch 89/100

1099/1099 - 2s - loss: 871.1688 - mse: 871.1688 - mae: 22.9819 - val_loss: 829.1918 - val_mse: 829.1918 - val_mae: 21.8905 - 2s/epoch - 2ms/step

Epoch 90/100

1099/1099 - 2s - loss: 870.4416 - mse: 870.4416 - mae: 22.9646 - val_loss: 832.3525 - val_mse: 832.3525 - val_mae: 22.0076 - 2s/epoch - 2ms/step

Epoch 91/100

1099/1099 - 2s - loss: 870.8822 - mse: 870.8822 - mae: 22.9612 - val_loss: 832.3726 - val_mse: 832.3726 - val_mae: 22.0124 - 2s/epoch - 2ms/step

Epoch 92/100

1099/1099 - 2s - loss: 870.1180 - mse: 870.1180 - mae: 22.9412 - val_loss: 834.2374 - val_mse: 834.2374 - val_mae: 22.0694 - 2s/epoch - 2ms/step

Epoch 93/100

1099/1099 - 2s - loss: 868.0063 - mse: 868.0063 - mae: 22.9041 - val_loss: 831.7313 - val_mse: 831.7313 - val_mae: 22.0004 - 2s/epoch - 2ms/step

Epoch 94/100

1099/1099 - 2s - loss: 870.9419 - mse: 870.9419 - mae: 22.9698 - val_loss: 832.8166 - val_mse: 832.8166 - val_mae: 21.9983 - 2s/epoch - 2ms/step

Epoch 95/100

1099/1099 - 2s - loss: 868.4117 - mse: 868.4117 - mae: 22.8738 - val_loss: 832.8957 - val_mse: 832.8957 - val_mae: 21.9811 - 2s/epoch - 2ms/step

Epoch 96/100

1099/1099 - 2s - loss: 867.2708 - mse: 867.2708 - mae: 22.8768 - val_loss: 829.9014 - val_mse: 829.9014 - val_mae: 21.9338 - 2s/epoch - 2ms/step

Epoch 97/100

1099/1099 - 2s - loss: 867.5429 - mse: 867.5429 - mae: 22.8736 - val_loss: 828.8050 - val_mse: 828.8050 - val_mae: 21.8792 - 2s/epoch - 2ms/step

Epoch 98/100

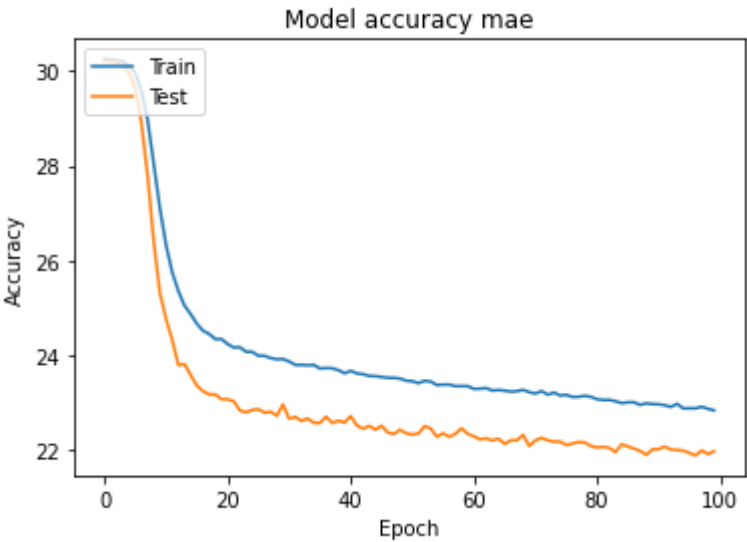
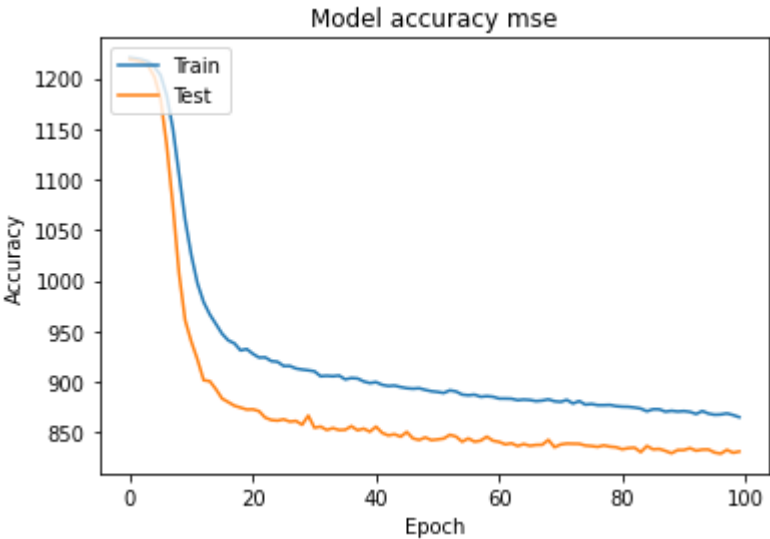
1099/1099 - 2s - loss: 868.5859 - mse: 868.5859 - mae: 22.9093 - val_loss: 832.5293 - val_mse: 832.5293 - val_mae: 21.9857 - 2s/epoch - 2ms/step

Epoch 99/100

1099/1099 - 2s - loss: 866.9859 - mse: 866.9859 - mae: 22.8657 - val_loss: 829.6936 - val_mse: 829.6936 - val_mae: 21.9082 - 2s/epoch - 2ms/step

Epoch 100/100

1099/1099 - 2s - loss: 864.8521 - mse: 864.8521 - mae: 22.8326 - val_loss: 830.9366 - val_mse: 830.9366 - val_mae: 21.9682 - 2s/epoch - 2ms/step



In []:

```
print("Combined phase and magnitude 1D CNN")

shape=(40,1)
filters=(8,8)
layers=(10,)
epochs = 25

phase = create_1d_cnn(shape, False, filters, layers, 'relu')
magnitude = create_1d_cnn(shape, False, filters, layers, 'relu')

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x=[x_train_magnitude, x_train_phase], y=y_train,
    validation_data=(x_test_magnitude, x_test_phase),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Combined phase and magnitude 1D CNN

Epoch 1/25

1099/1099 - 6s - loss: 1203.1497 - mse: 1203.1497 - mae: 29.9634 - val_loss: 1140.8578 - val_mse: 1140.8578 - val_mae: 29.0058 - 6s/epoch - 5ms/step

Epoch 2/25

1099/1099 - 5s - loss: 1114.0518 - mse: 1114.0518 - mae: 28.2260 - val_loss: 1067.7360 - val_mse: 1067.7360 - val_mae: 27.6349 - 5s/epoch - 4ms/step

Epoch 3/25

1099/1099 - 5s - loss: 1062.9465 - mse: 1062.9465 - mae: 27.1729 - val_loss: 1014.1903 - val_mse: 1014.1903 - val_mae: 26.6158 - 5s/epoch - 4ms/step

Epoch 4/25

1099/1099 - 5s - loss: 1026.8593 - mse: 1026.8593 - mae: 26.4198 - val_loss: 977.5419 - val_mse: 977.5419 - val_mae: 25.8245 - 5s/epoch - 4ms/step

Epoch 5/25

1099/1099 - 5s - loss: 993.2539 - mse: 993.2539 - mae: 25.7164 - val_loss: 937.0168 - val_mse: 937.0168 - val_mae: 24.9360 - 5s/epoch - 4ms/step

Epoch 6/25

1099/1099 - 5s - loss: 969.1327 - mse: 969.1327 - mae: 25.2381 - val_loss: 936.3973 - val_mse: 936.3973 - val_mae: 24.9285 - 5s/epoch - 4ms/step

Epoch 7/25

1099/1099 - 5s - loss: 954.7456 - mse: 954.7456 - mae: 24.9321 - val_loss: 950.3644 - val_mse: 950.3644 - val_mae: 25.2039 - 5s/epoch - 4ms/step

Epoch 8/25

1099/1099 - 5s - loss: 940.0179 - mse: 940.0179 - mae: 24.6252 - val_loss: 909.6603 - val_mse: 909.6603 - val_mae: 24.2852 - 5s/epoch - 4ms/step

Epoch 9/25

1099/1099 - 5s - loss: 932.3753 - mse: 932.3753 - mae: 24.4534 - val_loss: 897.2141 - val_mse: 897.2141 - val_mae: 23.9303 - 5s/epoch - 4ms/step

Epoch 10/25

1099/1099 - 5s - loss: 927.3021 - mse: 927.3021 - mae: 24.3397 - val_loss: 922.2180 - val_mse: 922.2180 - val_mae: 24.5623 - 5s/epoch - 4ms/step

Epoch 11/25

1099/1099 - 5s - loss: 920.0767 - mse: 920.0767 - mae: 24.1808 - val_loss: 939.2950 - val_mse: 939.2950 - val_mae: 24.9760 - 5s/epoch - 4ms/step

Epoch 12/25

1099/1099 - 5s - loss: 916.2521 - mse: 916.2521 - mae: 24.1042 - val_loss: 917.4622 - val_mse: 917.4622 - val_mae: 24.4643 - 5s/epoch - 4ms/step

Epoch 13/25

1099/1099 - 5s - loss: 912.7730 - mse: 912.7730 - mae: 24.0294 - val_loss: 922.3727 - val_mse: 922.3727 - val_mae: 24.5615 - 5s/epoch - 4ms/step

Epoch 14/25

1099/1099 - 5s - loss: 909.9955 - mse: 909.9955 - mae: 23.9493 - val_loss: 888.0841 - val_mse: 888.0841 - val_mae: 23.6994 - 5s/epoch - 4ms/step

Epoch 15/25

1099/1099 - 5s - loss: 906.5883 - mse: 906.5883 - mae: 23.8907 - val_loss: 870.2573 - val_mse: 870.2573 - val_mae: 23.1885 - 5s/epoch - 4ms/step

Epoch 16/25

1099/1099 - 5s - loss: 905.9901 - mse: 905.9901 - mae: 23.8674 - val_loss: 889.2960 - val_mse: 889.2960 - val_mae: 23.6967 - 5s/epoch - 4ms/step

Epoch 17/25

1099/1099 - 5s - loss: 903.4323 - mse: 903.4323 - mae: 23.8325 - val_loss: 881.3953 - val_mse: 881.3953 - val_mae: 23.5138 - 5s/epoch - 4ms/step

Epoch 18/25

1099/1099 - 5s - loss: 902.5614 - mse: 902.5614 - mae: 23.7865 - val_loss: 857.6465 - val_mse: 857.6465 - val_mae: 22.8319 - 5s/epoch - 5ms/step

Epoch 19/25

1099/1099 - 5s - loss: 900.6430 - mse: 900.6430 - mae: 23.7681 - val_loss: 902.0676 - val_mse: 902.0676 - val_mae: 24.0826 - 5s/epoch - 4ms/step

Epoch 20/25

1099/1099 - 5s - loss: 900.9426 - mse: 900.9426 - mae: 23.7547 - val_loss: 866.8986 - val_mse: 866.8986 - val_mae: 23.0591 - 5s/epoch - 4ms/step

Epoch 21/25

1099/1099 - 5s - loss: 898.8696 - mse: 898.8696 - mae: 23.7199 - val_loss: 860.7170 - val_mse: 860.7170 - val_mae: 22.9097 - 5s/epoch - 4ms/step

Epoch 22/25

1099/1099 - 5s - loss: 897.2820 - mse: 897.2820 - mae: 23.7051 - val_loss: 844.9313 - val_mse: 844.9313 - val_mae: 22.4540 - 5s/epoch - 4ms/step

Epoch 23/25

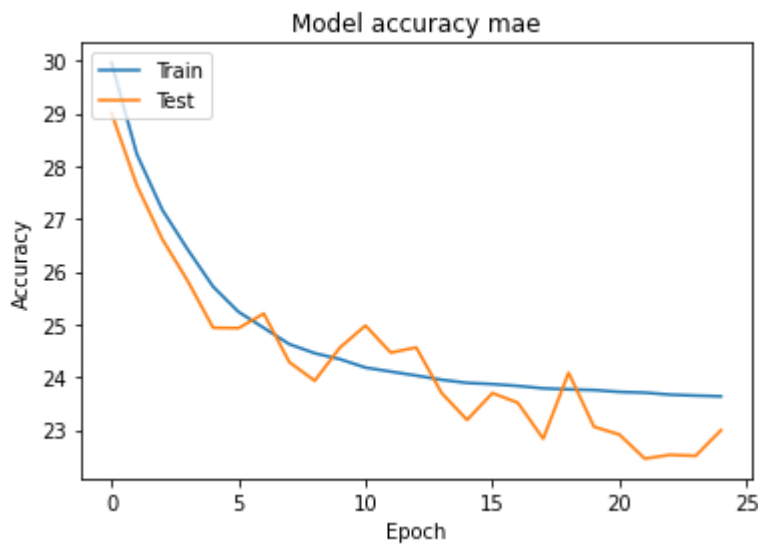
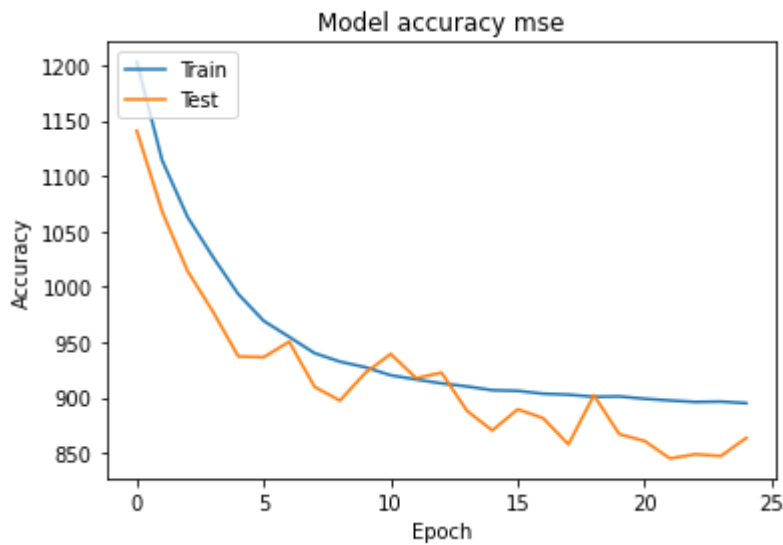
1099/1099 - 5s - loss: 895.9755 - mse: 895.9755 - mae: 23.6674 - val_loss: 848.7571 - val_mse: 848.7571 - val_mae: 22.5267 - 5s/epoch - 4ms/step

Epoch 24/25

1099/1099 - 5s - loss: 896.2991 - mse: 896.2991 - mae: 23.6496 - val_loss: 847.1276 - val_mse: 847.1276 - val_mae: 22.5064 - 5s/epoch - 4ms/step

Epoch 25/25

1099/1099 - 5s - loss: 894.8743 - mse: 894.8743 - mae: 23.6353 - val_loss: 863.4489 - val_mse: 863.4489 - val_mae: 22.9938 - 5s/epoch - 4ms/step



In []:

```
print("Individual phase MLP")

layers = (40,10)
shape = (40,)
epochs = 100

model = create_mlp(shape, layers, True, "relu")
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x= x_train_phase, y=y_train,
    validation_data=(x_test_phase, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual phase MLP

Epoch 1/100

1099/1099 - 2s - loss: 1220.7994 - mse: 1220.7994 - mae: 30.2646 - val_loss: 1219.0101 - val_mse: 1219.0101 - val_mae: 30.2238 - 2s/epoch - 2ms/step

Epoch 2/100

1099/1099 - 2s - loss: 1220.1207 - mse: 1220.1207 - mae: 30.2566 - val_loss: 1218.6829 - val_mse: 1218.6829 - val_mae: 30.2189 - 2s/epoch - 2ms/step

Epoch 3/100

1099/1099 - 2s - loss: 1219.4867 - mse: 1219.4867 - mae: 30.2477 - val_loss: 1218.0746 - val_mse: 1218.0746 - val_mae: 30.2099 - 2s/epoch - 2ms/step

Epoch 4/100

1099/1099 - 2s - loss: 1218.8517 - mse: 1218.8517 - mae: 30.2390 - val_loss: 1216.9022 - val_mse: 1216.9022 - val_mae: 30.1943 - 2s/epoch - 2ms/step

Epoch 5/100

1099/1099 - 2s - loss: 1217.2185 - mse: 1217.2185 - mae: 30.2120 - val_loss: 1214.0962 - val_mse: 1214.0962 - val_mae: 30.1548 - 2s/epoch - 2ms/step

Epoch 6/100

1099/1099 - 2s - loss: 1214.6284 - mse: 1214.6284 - mae: 30.1688 - val_loss: 1208.9874 - val_mse: 1208.9874 - val_mae: 30.0822 - 2s/epoch - 2ms/step

Epoch 7/100

1099/1099 - 2s - loss: 1210.0157 - mse: 1210.0157 - mae: 30.0976 - val_loss: 1200.1415 - val_mse: 1200.1415 - val_mae: 29.9553 - 2s/epoch - 2ms/step

Epoch 8/100

1099/1099 - 2s - loss: 1201.8690 - mse: 1201.8690 - mae: 29.9602 - val_loss: 1185.4940 - val_mse: 1185.4940 - val_mae: 29.7449 - 2s/epoch - 2ms/step

Epoch 9/100

1099/1099 - 2s - loss: 1191.2990 - mse: 1191.2990 - mae: 29.7913 - val_loss: 1165.0873 - val_mse: 1165.0873 - val_mae: 29.4413 - 2s/epoch - 2ms/step

Epoch 10/100

1099/1099 - 2s - loss: 1175.6743 - mse: 1175.6743 - mae: 29.5177 - val_loss: 1140.2939 - val_mse: 1140.2939 - val_mae: 29.0461 - 2s/epoch - 2ms/step

Epoch 11/100

1099/1099 - 2s - loss: 1158.3508 - mse: 1158.3508 - mae: 29.1980 - val_loss: 1112.2144 - val_mse: 1112.2144 - val_mae: 28.5713 - 2s/epoch - 2ms/step

Epoch 12/100

1099/1099 - 2s - loss: 1138.4724 - mse: 1138.4724 - mae: 28.8123 - val_loss: 1081.6156 - val_mse: 1081.6156 - val_mae: 28.0133 - 2s/epoch - 2ms/step

Epoch 13/100

1099/1099 - 2s - loss: 1120.9288 - mse: 1120.9288 - mae: 28.4275 - val_loss: 1056.0359 - val_mse: 1056.0359 - val_mae: 27.5060 - 2s/epoch - 2ms/step

Epoch 14/100

1099/1099 - 2s - loss: 1101.6400 - mse: 1101.6400 - mae: 28.0541 - val_loss: 1033.6732 - val_mse: 1033.6732 - val_mae: 27.0362 - 2s/epoch - 2ms/step

Epoch 15/100

1099/1099 - 2s - loss: 1085.2581 - mse: 1085.2581 - mae: 27.6882 - val_loss: 1012.8392 - val_mse: 1012.8392 - val_mae: 26.5663 - 2s/epoch - 2ms/step

Epoch 16/100

1099/1099 - 2s - loss: 1070.3907 - mse: 1070.3907 - mae: 27.3776 - val_loss: 996.7193 - val_mse: 996.7193 - val_mae: 26.2244 - 2s/epoch - 2ms/step

Epoch 17/100

1099/1099 - 2s - loss: 1060.3223 - mse: 1060.3223 - mae: 27.1376 - val_loss: 982.4687 - val_mse: 982.4687 - val_mae: 25.8766 - 2s/epoch - 2ms/step

Epoch 18/100

1099/1099 - 2s - loss: 1050.6375 - mse: 1050.6375 - mae: 26.8975 - val_loss: 970.7778 - val_mse: 970.7778 - val_mae: 25.6015 - 2s/epoch - 2ms/step

Epoch 19/100

1099/1099 - 2s - loss: 1038.8285 - mse: 1038.8285 - mae: 26.6628 - val_loss: 959.8481 - val_mse: 959.8481 - val_mae: 25.3213 - 2s/epoch - 2ms/step

Epoch 20/100

1099/1099 - 2s - loss: 1032.2521 - mse: 1032.2521 - mae: 26.5072 - val_loss: 954.7056 - val_mse: 954.7056 - val_mae: 25.1884 - 2s/epoch - 2ms/step

Epoch 21/100

1099/1099 - 2s - loss: 1026.1938 - mse: 1026.1938 - mae: 26.3651 - val_loss: 947.3969 - val_mse: 947.3969 - val_mae: 25.0248 - 2s/epoch - 2ms/step

Epoch 22/100

1099/1099 - 2s - loss: 1019.5846 - mse: 1019.5846 - mae: 26.2230 - val_loss: 942.9078 - val_mse: 942.9078 - val_mae: 24.9202 - 2s/epoch - 2ms/step

Epoch 23/100

1099/1099 - 2s - loss: 1014.6760 - mse: 1014.6760 - mae: 26.1266 - val_loss: 931.1618 - val_mse: 931.1618 - val_mae: 24.5814 - 2s/epoch - 2ms/step

Epoch 24/100

1099/1099 - 2s - loss: 1012.2065 - mse: 1012.2065 - mae: 26.0079 - val_loss: 927.3939 - val_mse: 927.3939 - val_mae: 24.5084 - 2s/epoch - 2ms/step

Epoch 25/100

1099/1099 - 2s - loss: 1007.4680 - mse: 1007.4680 - mae: 25.9142 - val_loss: 927.9357 - val_mse: 927.9357 - val_mae: 24.5367 - 2s/epoch - 2ms/step

Epoch 26/100

1099/1099 - 2s - loss: 1001.3428 - mse: 1001.3428 - mae: 25.7978 - val_loss: 918.6844 - val_mse: 918.6844 - val_mae: 24.2545 - 2s/epoch - 2ms/step

Epoch 27/100

1099/1099 - 2s - loss: 999.0605 - mse: 999.0605 - mae: 25.7626 - val_loss: 915.8298 - val_mse: 915.8298 - val_mae: 24.1903 - 2s/epoch - 2ms/step

Epoch 28/100

1099/1099 - 2s - loss: 997.3719 - mse: 997.3719 - mae: 25.6927 - val_loss: 916.0436 - val_mse: 916.0436 - val_mae: 24.2153 - 2s/epoch - 2ms/step

Epoch 29/100

1099/1099 - 2s - loss: 994.4683 - mse: 994.4683 - mae: 25.6185 - val_loss: 915.2094 - val_mse: 915.2094 - val_mae: 24.2212 - 2s/epoch - 2ms/step

Epoch 30/100

1099/1099 - 2s - loss: 989.9358 - mse: 989.9358 - mae: 25.5440 - val_loss: 911.7891 - val_mse: 911.7891 - val_mae: 24.0786 - 2s/epoch - 2ms/step

Epoch 31/100

1099/1099 - 2s - loss: 989.4338 - mse: 989.4338 - mae: 25.5108 - val_loss: 911.5358 - val_mse: 911.5358 - val_mae: 24.1085 - 2s/epoch - 2ms/step

Epoch 32/100

1099/1099 - 2s - loss: 985.0543 - mse: 985.0543 - mae: 25.4161 - val_loss: 905.3457 - val_mse: 905.3457 - val_mae: 23.9087 - 2s/epoch - 2ms/step

Epoch 33/100

1099/1099 - 2s - loss: 983.9442 - mse: 983.9442 - mae: 25.3890 - val_loss: 906.1287 - val_mse: 906.1287 - val_mae: 23.9242 - 2s/epoch - 2ms/step

Epoch 34/100

1099/1099 - 2s - loss: 982.0063 - mse: 982.0063 - mae: 25.3572 - val_loss: 903.2968 - val_mse: 903.2968 - val_mae: 23.8769 - 2s/epoch - 2ms/step

Epoch 35/100

1099/1099 - 2s - loss: 979.6460 - mse: 979.6460 - mae: 25.3098 - val_loss: 902.8743 - val_mse: 902.8743 - val_mae: 23.8526 - 2s/epoch - 2ms/step

Epoch 36/100

1099/1099 - 2s - loss: 978.0568 - mse: 978.0568 - mae: 25.2750 - val_loss: 898.6016 - val_mse: 898.6016 - val_mae: 23.7561 - 2s/epoch - 2ms/step

Epoch 37/100

1099/1099 - 2s - loss: 978.8148 - mse: 978.8148 - mae: 25.2869 - val_loss: 900.2835 - val_mse: 900.2835 - val_mae: 23.7798 - 2s/epoch - 2ms/step

Epoch 38/100

1099/1099 - 2s - loss: 978.5563 - mse: 978.5563 - mae: 25.2631 - val_loss: 901.2811 - val_mse: 901.2811 - val_mae: 23.8062 - 2s/epoch - 2ms/step

Epoch 39/100

1099/1099 - 2s - loss: 977.3940 - mse: 977.3940 - mae: 25.2432 - val_loss: 897.2619 - val_mse: 897.2619 - val_mae: 23.6963 - 2s/epoch - 2ms/step

Epoch 40/100

1099/1099 - 2s - loss: 975.4884 - mse: 975.4884 - mae: 25.2216 - val_loss: 901.4560 - val_mse: 901.4560 - val_mae: 23.7931 - 2s/epoch - 2ms/step

Epoch 41/100

1099/1099 - 2s - loss: 974.0361 - mse: 974.0361 - mae: 25.1718 - val_loss: 891.1047 - val_mse: 891.1047 - val_mae: 23.5057 - 2s/epoch - 2ms/step
Epoch 42/100
1099/1099 - 2s - loss: 971.5655 - mse: 971.5655 - mae: 25.1343 - val_loss: 893.9786 - val_mse: 893.9786 - val_mae: 23.6172 - 2s/epoch - 2ms/step
Epoch 43/100
1099/1099 - 2s - loss: 971.9574 - mse: 971.9574 - mae: 25.1415 - val_loss: 891.4066 - val_mse: 891.4066 - val_mae: 23.5089 - 2s/epoch - 2ms/step
Epoch 44/100
1099/1099 - 2s - loss: 973.5356 - mse: 973.5356 - mae: 25.1523 - val_loss: 894.1364 - val_mse: 894.1364 - val_mae: 23.6528 - 2s/epoch - 2ms/step
Epoch 45/100
1099/1099 - 2s - loss: 974.3461 - mse: 974.3461 - mae: 25.1631 - val_loss: 889.3727 - val_mse: 889.3727 - val_mae: 23.4578 - 2s/epoch - 2ms/step
Epoch 46/100
1099/1099 - 2s - loss: 972.1186 - mse: 972.1186 - mae: 25.1329 - val_loss: 890.2012 - val_mse: 890.2012 - val_mae: 23.5012 - 2s/epoch - 2ms/step
Epoch 47/100
1099/1099 - 2s - loss: 970.1096 - mse: 970.1096 - mae: 25.1059 - val_loss: 892.5995 - val_mse: 892.5995 - val_mae: 23.5938 - 2s/epoch - 2ms/step
Epoch 48/100
1099/1099 - 2s - loss: 969.5078 - mse: 969.5078 - mae: 25.0995 - val_loss: 889.3579 - val_mse: 889.3579 - val_mae: 23.4875 - 2s/epoch - 2ms/step
Epoch 49/100
1099/1099 - 2s - loss: 970.2609 - mse: 970.2609 - mae: 25.0915 - val_loss: 898.5076 - val_mse: 898.5076 - val_mae: 23.6990 - 2s/epoch - 2ms/step
Epoch 50/100
1099/1099 - 2s - loss: 970.0972 - mse: 970.0972 - mae: 25.0952 - val_loss: 891.5193 - val_mse: 891.5193 - val_mae: 23.5126 - 2s/epoch - 2ms/step
Epoch 51/100
1099/1099 - 2s - loss: 972.0975 - mse: 972.0975 - mae: 25.1100 - val_loss: 891.6940 - val_mse: 891.6940 - val_mae: 23.5225 - 2s/epoch - 2ms/step
Epoch 52/100
1099/1099 - 2s - loss: 971.8251 - mse: 971.8251 - mae: 25.1294 - val_loss: 894.1135 - val_mse: 894.1135 - val_mae: 23.5998 - 2s/epoch - 2ms/step
Epoch 53/100
1099/1099 - 2s - loss: 969.5180 - mse: 969.5180 - mae: 25.1008 - val_loss: 892.4149 - val_mse: 892.4149 - val_mae: 23.5788 - 2s/epoch - 2ms/step
Epoch 54/100
1099/1099 - 2s - loss: 970.0803 - mse: 970.0803 - mae: 25.0857 - val_loss: 892.9203 - val_mse: 892.9203 - val_mae: 23.6022 - 2s/epoch - 2ms/step
Epoch 55/100
1099/1099 - 2s - loss: 968.4579 - mse: 968.4579 - mae: 25.0629 - val_loss: 891.8474 - val_mse: 891.8474 - val_mae: 23.5584 - 2s/epoch - 2ms/step
Epoch 56/100
1099/1099 - 2s - loss: 969.3886 - mse: 969.3886 - mae: 25.0783 - val_loss: 890.6089 - val_mse: 890.6089 - val_mae: 23.5039 - 2s/epoch - 2ms/step
Epoch 57/100
1099/1099 - 2s - loss: 966.5508 - mse: 966.5508 - mae: 25.0212 - val_loss: 889.3111 - val_mse: 889.3111 - val_mae: 23.4881 - 2s/epoch - 2ms/step
Epoch 58/100
1099/1099 - 2s - loss: 968.2852 - mse: 968.2852 - mae: 25.0514 - val_loss: 891.6725 - val_mse: 891.6725 - val_mae: 23.5135 - 2s/epoch - 2ms/step
Epoch 59/100
1099/1099 - 2s - loss: 966.8228 - mse: 966.8228 - mae: 25.0260 - val_loss: 893.2197 - val_mse: 893.2197 - val_mae: 23.6044 - 2s/epoch - 2ms/step
Epoch 60/100
1099/1099 - 2s - loss: 968.1570 - mse: 968.1570 - mae: 25.0512 - val_loss: 888.5425 - val_mse: 888.5425 - val_mae: 23.4525 - 2s/epoch - 2ms/step
Epoch 61/100
1099/1099 - 2s - loss: 969.4621 - mse: 969.4621 - mae: 25.0721 - val_loss:

892.6307 - val_mse: 892.6307 - val_mae: 23.5911 - 2s/epoch - 2ms/step
Epoch 62/100
1099/1099 - 2s - loss: 967.4570 - mse: 967.4570 - mae: 25.0462 - val_loss:
890.0200 - val_mse: 890.0200 - val_mae: 23.5247 - 2s/epoch - 2ms/step
Epoch 63/100
1099/1099 - 2s - loss: 966.7222 - mse: 966.7222 - mae: 25.0336 - val_loss:
889.0497 - val_mse: 889.0497 - val_mae: 23.5106 - 2s/epoch - 2ms/step
Epoch 64/100
1099/1099 - 2s - loss: 966.8611 - mse: 966.8611 - mae: 25.0302 - val_loss:
888.8545 - val_mse: 888.8545 - val_mae: 23.4829 - 2s/epoch - 2ms/step
Epoch 65/100
1099/1099 - 2s - loss: 965.4315 - mse: 965.4315 - mae: 24.9790 - val_loss:
884.7938 - val_mse: 884.7938 - val_mae: 23.3705 - 2s/epoch - 2ms/step
Epoch 66/100
1099/1099 - 2s - loss: 966.5607 - mse: 966.5607 - mae: 25.0472 - val_loss:
890.1377 - val_mse: 890.1377 - val_mae: 23.5305 - 2s/epoch - 2ms/step
Epoch 67/100
1099/1099 - 2s - loss: 966.4540 - mse: 966.4540 - mae: 25.0158 - val_loss:
890.7574 - val_mse: 890.7574 - val_mae: 23.5270 - 2s/epoch - 2ms/step
Epoch 68/100
1099/1099 - 2s - loss: 965.4521 - mse: 965.4521 - mae: 24.9906 - val_loss:
890.6625 - val_mse: 890.6625 - val_mae: 23.5405 - 2s/epoch - 2ms/step
Epoch 69/100
1099/1099 - 2s - loss: 964.5867 - mse: 964.5867 - mae: 24.9867 - val_loss:
886.2676 - val_mse: 886.2676 - val_mae: 23.4058 - 2s/epoch - 2ms/step
Epoch 70/100
1099/1099 - 2s - loss: 967.7299 - mse: 967.7299 - mae: 25.0356 - val_loss:
883.0703 - val_mse: 883.0703 - val_mae: 23.2999 - 2s/epoch - 2ms/step
Epoch 71/100
1099/1099 - 2s - loss: 964.2249 - mse: 964.2249 - mae: 24.9812 - val_loss:
885.4985 - val_mse: 885.4985 - val_mae: 23.4100 - 2s/epoch - 2ms/step
Epoch 72/100
1099/1099 - 2s - loss: 961.5230 - mse: 961.5230 - mae: 24.9224 - val_loss:
885.4434 - val_mse: 885.4434 - val_mae: 23.3898 - 2s/epoch - 2ms/step
Epoch 73/100
1099/1099 - 2s - loss: 964.3578 - mse: 964.3578 - mae: 24.9719 - val_loss:
885.1948 - val_mse: 885.1948 - val_mae: 23.3661 - 2s/epoch - 2ms/step
Epoch 74/100
1099/1099 - 2s - loss: 964.3696 - mse: 964.3696 - mae: 24.9778 - val_loss:
889.7591 - val_mse: 889.7591 - val_mae: 23.5112 - 2s/epoch - 2ms/step
Epoch 75/100
1099/1099 - 2s - loss: 964.2675 - mse: 964.2675 - mae: 24.9677 - val_loss:
887.6771 - val_mse: 887.6771 - val_mae: 23.4663 - 2s/epoch - 2ms/step
Epoch 76/100
1099/1099 - 2s - loss: 963.1295 - mse: 963.1295 - mae: 24.9544 - val_loss:
886.9170 - val_mse: 886.9170 - val_mae: 23.4347 - 2s/epoch - 2ms/step
Epoch 77/100
1099/1099 - 2s - loss: 962.4908 - mse: 962.4908 - mae: 24.9363 - val_loss:
885.7575 - val_mse: 885.7575 - val_mae: 23.3658 - 2s/epoch - 2ms/step
Epoch 78/100
1099/1099 - 2s - loss: 963.7051 - mse: 963.7051 - mae: 24.9414 - val_loss:
885.3516 - val_mse: 885.3516 - val_mae: 23.3650 - 2s/epoch - 2ms/step
Epoch 79/100
1099/1099 - 2s - loss: 961.4488 - mse: 961.4488 - mae: 24.9145 - val_loss:
887.3421 - val_mse: 887.3421 - val_mae: 23.4510 - 2s/epoch - 2ms/step
Epoch 80/100
1099/1099 - 2s - loss: 963.2063 - mse: 963.2063 - mae: 24.9364 - val_loss:
890.1075 - val_mse: 890.1075 - val_mae: 23.5206 - 2s/epoch - 2ms/step
Epoch 81/100
1099/1099 - 2s - loss: 962.6424 - mse: 962.6424 - mae: 24.9203 - val_loss:
885.6673 - val_mse: 885.6673 - val_mae: 23.4404 - 2s/epoch - 2ms/step

Epoch 82/100

1099/1099 - 2s - loss: 960.9761 - mse: 960.9761 - mae: 24.9036 - val_loss: 884.7856 - val_mse: 884.7856 - val_mae: 23.3886 - 2s/epoch - 2ms/step

Epoch 83/100

1099/1099 - 2s - loss: 961.6438 - mse: 961.6438 - mae: 24.9090 - val_loss: 881.3885 - val_mse: 881.3885 - val_mae: 23.2523 - 2s/epoch - 2ms/step

Epoch 84/100

1099/1099 - 2s - loss: 961.5080 - mse: 961.5080 - mae: 24.9022 - val_loss: 885.8851 - val_mse: 885.8851 - val_mae: 23.4222 - 2s/epoch - 2ms/step

Epoch 85/100

1099/1099 - 2s - loss: 960.5123 - mse: 960.5123 - mae: 24.8758 - val_loss: 880.8307 - val_mse: 880.8307 - val_mae: 23.2547 - 2s/epoch - 2ms/step

Epoch 86/100

1099/1099 - 2s - loss: 959.0917 - mse: 959.0917 - mae: 24.8750 - val_loss: 883.4612 - val_mse: 883.4612 - val_mae: 23.3731 - 2s/epoch - 2ms/step

Epoch 87/100

1099/1099 - 2s - loss: 958.5144 - mse: 958.5144 - mae: 24.8507 - val_loss: 881.5181 - val_mse: 881.5181 - val_mae: 23.2980 - 2s/epoch - 2ms/step

Epoch 88/100

1099/1099 - 2s - loss: 961.8716 - mse: 961.8716 - mae: 24.9148 - val_loss: 883.5326 - val_mse: 883.5326 - val_mae: 23.3896 - 2s/epoch - 2ms/step

Epoch 89/100

1099/1099 - 2s - loss: 960.0946 - mse: 960.0946 - mae: 24.8905 - val_loss: 883.6638 - val_mse: 883.6638 - val_mae: 23.3681 - 2s/epoch - 2ms/step

Epoch 90/100

1099/1099 - 2s - loss: 961.1993 - mse: 961.1993 - mae: 24.8960 - val_loss: 881.8096 - val_mse: 881.8096 - val_mae: 23.2864 - 2s/epoch - 2ms/step

Epoch 91/100

1099/1099 - 2s - loss: 960.0361 - mse: 960.0361 - mae: 24.8691 - val_loss: 885.7777 - val_mse: 885.7777 - val_mae: 23.4533 - 2s/epoch - 2ms/step

Epoch 92/100

1099/1099 - 2s - loss: 959.9489 - mse: 959.9489 - mae: 24.8713 - val_loss: 884.4258 - val_mse: 884.4258 - val_mae: 23.3803 - 2s/epoch - 2ms/step

Epoch 93/100

1099/1099 - 2s - loss: 960.7307 - mse: 960.7307 - mae: 24.9116 - val_loss: 883.9259 - val_mse: 883.9259 - val_mae: 23.3614 - 2s/epoch - 2ms/step

Epoch 94/100

1099/1099 - 2s - loss: 958.0213 - mse: 958.0213 - mae: 24.8655 - val_loss: 880.6465 - val_mse: 880.6465 - val_mae: 23.2300 - 2s/epoch - 2ms/step

Epoch 95/100

1099/1099 - 2s - loss: 958.5931 - mse: 958.5931 - mae: 24.8594 - val_loss: 882.8694 - val_mse: 882.8694 - val_mae: 23.3346 - 2s/epoch - 2ms/step

Epoch 96/100

1099/1099 - 2s - loss: 958.3566 - mse: 958.3566 - mae: 24.8703 - val_loss: 886.8538 - val_mse: 886.8538 - val_mae: 23.4518 - 2s/epoch - 2ms/step

Epoch 97/100

1099/1099 - 2s - loss: 959.7771 - mse: 959.7771 - mae: 24.8805 - val_loss: 884.8133 - val_mse: 884.8133 - val_mae: 23.3573 - 2s/epoch - 2ms/step

Epoch 98/100

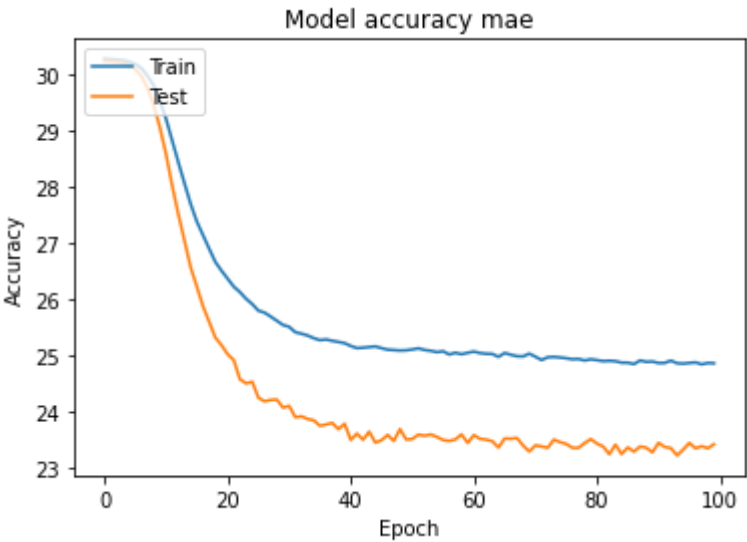
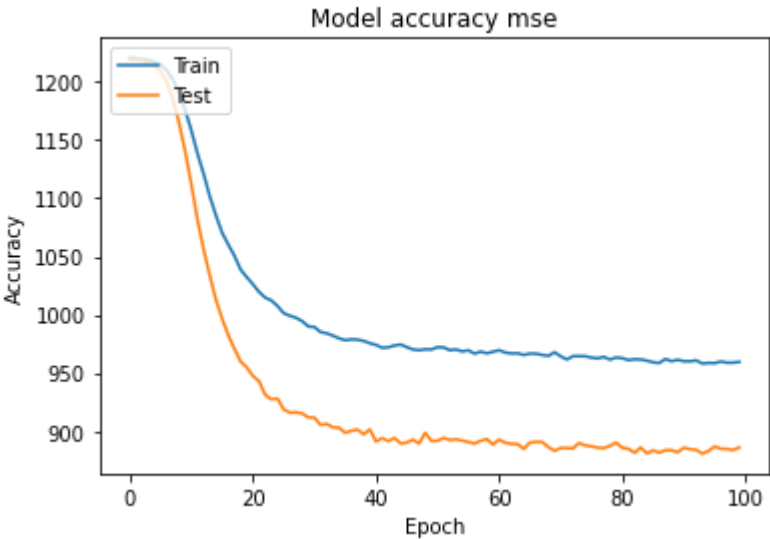
1099/1099 - 2s - loss: 958.7736 - mse: 958.7736 - mae: 24.8466 - val_loss: 884.6906 - val_mse: 884.6906 - val_mae: 23.3938 - 2s/epoch - 2ms/step

Epoch 99/100

1099/1099 - 2s - loss: 958.8351 - mse: 958.8351 - mae: 24.8700 - val_loss: 883.6988 - val_mse: 883.6988 - val_mae: 23.3576 - 2s/epoch - 2ms/step

Epoch 100/100

1099/1099 - 2s - loss: 959.3964 - mse: 959.3964 - mae: 24.8648 - val_loss: 885.9979 - val_mse: 885.9979 - val_mae: 23.4285 - 2s/epoch - 2ms/step



In []:

```
print("Individual magnitude MLP")

layers = (40,10)
shape = (40,)
epochs = 100
model = create_mlp(shape, layers, True, "relu")
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x= x_train_magnitude, y=y_train,
    validation_data=(x_test_magnitude, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual magnitude MLP

Epoch 1/100

1099/1099 - 3s - loss: 1220.2557 - mse: 1220.2557 - mae: 30.2592 - val_loss: 1218.2856 - val_mse: 1218.2856 - val_mae: 30.2149 - 3s/epoch - 2ms/step

Epoch 2/100

1099/1099 - 2s - loss: 1219.3306 - mse: 1219.3306 - mae: 30.2459 - val_loss: 1217.6312 - val_mse: 1217.6312 - val_mae: 30.2051 - 2s/epoch - 2ms/step

Epoch 3/100

1099/1099 - 2s - loss: 1218.5815 - mse: 1218.5815 - mae: 30.2347 - val_loss: 1216.7948 - val_mse: 1216.7948 - val_mae: 30.1923 - 2s/epoch - 2ms/step

Epoch 4/100

1099/1099 - 2s - loss: 1217.4507 - mse: 1217.4507 - mae: 30.2172 - val_loss: 1215.3491 - val_mse: 1215.3491 - val_mae: 30.1700 - 2s/epoch - 2ms/step

Epoch 5/100

1099/1099 - 2s - loss: 1215.6976 - mse: 1215.6976 - mae: 30.1881 - val_loss: 1212.8698 - val_mse: 1212.8698 - val_mae: 30.1329 - 2s/epoch - 2ms/step

Epoch 6/100

1099/1099 - 2s - loss: 1213.4624 - mse: 1213.4624 - mae: 30.1493 - val_loss: 1207.9664 - val_mse: 1207.9664 - val_mae: 30.0620 - 2s/epoch - 2ms/step

Epoch 7/100

1099/1099 - 2s - loss: 1208.3265 - mse: 1208.3265 - mae: 30.0630 - val_loss: 1198.7013 - val_mse: 1198.7013 - val_mae: 29.9214 - 2s/epoch - 2ms/step

Epoch 8/100

1099/1099 - 2s - loss: 1200.3424 - mse: 1200.3424 - mae: 29.9280 - val_loss: 1185.4648 - val_mse: 1185.4648 - val_mae: 29.7259 - 2s/epoch - 2ms/step

Epoch 9/100

1099/1099 - 2s - loss: 1188.2352 - mse: 1188.2352 - mae: 29.7177 - val_loss: 1163.8896 - val_mse: 1163.8896 - val_mae: 29.3856 - 2s/epoch - 2ms/step

Epoch 10/100

1099/1099 - 2s - loss: 1170.2524 - mse: 1170.2524 - mae: 29.4052 - val_loss: 1135.7555 - val_mse: 1135.7555 - val_mae: 28.9127 - 2s/epoch - 2ms/step

Epoch 11/100

1099/1099 - 2s - loss: 1146.0847 - mse: 1146.0847 - mae: 28.9334 - val_loss: 1100.5253 - val_mse: 1100.5253 - val_mae: 28.2706 - 2s/epoch - 2ms/step

Epoch 12/100

1099/1099 - 2s - loss: 1120.6426 - mse: 1120.6426 - mae: 28.4319 - val_loss: 1065.0449 - val_mse: 1065.0449 - val_mae: 27.5648 - 2s/epoch - 2ms/step

Epoch 13/100

1099/1099 - 2s - loss: 1093.5935 - mse: 1093.5935 - mae: 27.8481 - val_loss: 1032.1112 - val_mse: 1032.1112 - val_mae: 26.8258 - 2s/epoch - 2ms/step

Epoch 14/100

1099/1099 - 2s - loss: 1067.4276 - mse: 1067.4276 - mae: 27.2741 - val_loss: 1014.0146 - val_mse: 1014.0146 - val_mae: 26.4349 - 2s/epoch - 2ms/step

Epoch 15/100

1099/1099 - 2s - loss: 1047.6633 - mse: 1047.6633 - mae: 26.8232 - val_loss: 987.7766 - val_mse: 987.7766 - val_mae: 25.7904 - 2s/epoch - 2ms/step

Epoch 16/100

1099/1099 - 2s - loss: 1034.3948 - mse: 1034.3948 - mae: 26.5189 - val_loss: 970.4828 - val_mse: 970.4828 - val_mae: 25.3757 - 2s/epoch - 2ms/step

Epoch 17/100

1099/1099 - 2s - loss: 1023.3001 - mse: 1023.3001 - mae: 26.2418 - val_loss: 960.2880 - val_mse: 960.2880 - val_mae: 25.1080 - 2s/epoch - 2ms/step

Epoch 18/100

1099/1099 - 2s - loss: 1015.7160 - mse: 1015.7160 - mae: 26.0718 - val_loss: 952.1559 - val_mse: 952.1559 - val_mae: 24.9322 - 2s/epoch - 2ms/step

Epoch 19/100

1099/1099 - 2s - loss: 1007.2747 - mse: 1007.2747 - mae: 25.8845 - val_loss: 943.1976 - val_mse: 943.1976 - val_mae: 24.7083 - 2s/epoch - 2ms/step

Epoch 20/100

1099/1099 - 2s - loss: 999.9457 - mse: 999.9457 - mae: 25.7493 - val_loss: 939.4337 - val_mse: 939.4337 - val_mae: 24.5636 - 2s/epoch - 2ms/step

Epoch 21/100

1099/1099 - 2s - loss: 995.2439 - mse: 995.2439 - mae: 25.6316 - val_loss: 931.9474 - val_mse: 931.9474 - val_mae: 24.3956 - 2s/epoch - 2ms/step

Epoch 22/100

1099/1099 - 2s - loss: 990.1621 - mse: 990.1621 - mae: 25.5175 - val_loss: 931.9622 - val_mse: 931.9622 - val_mae: 24.3584 - 2s/epoch - 2ms/step

Epoch 23/100

1099/1099 - 2s - loss: 986.3395 - mse: 986.3395 - mae: 25.4524 - val_loss: 923.3311 - val_mse: 923.3311 - val_mae: 24.1685 - 2s/epoch - 2ms/step

Epoch 24/100

1099/1099 - 2s - loss: 985.0370 - mse: 985.0370 - mae: 25.4221 - val_loss: 921.6813 - val_mse: 921.6813 - val_mae: 24.1278 - 2s/epoch - 2ms/step

Epoch 25/100

1099/1099 - 2s - loss: 982.9198 - mse: 982.9198 - mae: 25.3454 - val_loss: 923.5245 - val_mse: 923.5245 - val_mae: 24.1849 - 2s/epoch - 2ms/step

Epoch 26/100

1099/1099 - 2s - loss: 978.4804 - mse: 978.4804 - mae: 25.2673 - val_loss: 920.8469 - val_mse: 920.8469 - val_mae: 24.0939 - 2s/epoch - 2ms/step

Epoch 27/100

1099/1099 - 2s - loss: 976.8064 - mse: 976.8064 - mae: 25.2325 - val_loss: 917.7762 - val_mse: 917.7762 - val_mae: 24.0547 - 2s/epoch - 2ms/step

Epoch 28/100

1099/1099 - 2s - loss: 974.7880 - mse: 974.7880 - mae: 25.1920 - val_loss: 908.2974 - val_mse: 908.2974 - val_mae: 23.8070 - 2s/epoch - 2ms/step

Epoch 29/100

1099/1099 - 2s - loss: 972.5767 - mse: 972.5767 - mae: 25.1424 - val_loss: 911.6095 - val_mse: 911.6095 - val_mae: 23.9607 - 2s/epoch - 2ms/step

Epoch 30/100

1099/1099 - 2s - loss: 972.4830 - mse: 972.4830 - mae: 25.1342 - val_loss: 911.1509 - val_mse: 911.1509 - val_mae: 23.9334 - 2s/epoch - 2ms/step

Epoch 31/100

1099/1099 - 2s - loss: 967.6675 - mse: 967.6675 - mae: 25.0527 - val_loss: 905.3203 - val_mse: 905.3203 - val_mae: 23.7792 - 2s/epoch - 2ms/step

Epoch 32/100

1099/1099 - 2s - loss: 967.5992 - mse: 967.5992 - mae: 25.0402 - val_loss: 908.3079 - val_mse: 908.3079 - val_mae: 23.8312 - 2s/epoch - 2ms/step

Epoch 33/100

1099/1099 - 2s - loss: 964.8047 - mse: 964.8047 - mae: 24.9931 - val_loss: 903.5099 - val_mse: 903.5099 - val_mae: 23.7421 - 2s/epoch - 2ms/step

Epoch 34/100

1099/1099 - 2s - loss: 964.9670 - mse: 964.9670 - mae: 24.9831 - val_loss: 905.6059 - val_mse: 905.6059 - val_mae: 23.8168 - 2s/epoch - 2ms/step

Epoch 35/100

1099/1099 - 2s - loss: 964.0454 - mse: 964.0454 - mae: 24.9971 - val_loss: 896.8386 - val_mse: 896.8386 - val_mae: 23.5352 - 2s/epoch - 2ms/step

Epoch 36/100

1099/1099 - 2s - loss: 961.4042 - mse: 961.4042 - mae: 24.9212 - val_loss: 896.6725 - val_mse: 896.6725 - val_mae: 23.5395 - 2s/epoch - 2ms/step

Epoch 37/100

1099/1099 - 2s - loss: 961.5294 - mse: 961.5294 - mae: 24.9275 - val_loss: 899.2841 - val_mse: 899.2841 - val_mae: 23.6008 - 2s/epoch - 2ms/step

Epoch 38/100

1099/1099 - 2s - loss: 958.0375 - mse: 958.0375 - mae: 24.8333 - val_loss: 895.1096 - val_mse: 895.1096 - val_mae: 23.5114 - 2s/epoch - 2ms/step

Epoch 39/100

1099/1099 - 2s - loss: 959.5217 - mse: 959.5217 - mae: 24.8629 - val_loss: 899.4780 - val_mse: 899.4780 - val_mae: 23.6326 - 2s/epoch - 2ms/step

Epoch 40/100

1099/1099 - 2s - loss: 957.7942 - mse: 957.7942 - mae: 24.8461 - val_loss: 894.9993 - val_mse: 894.9993 - val_mae: 23.5276 - 2s/epoch - 2ms/step

Epoch 41/100

1099/1099 - 2s - loss: 958.5789 - mse: 958.5789 - mae: 24.8562 - val_loss: 895.1379 - val_mse: 895.1379 - val_mae: 23.5499 - 2s/epoch - 2ms/step
Epoch 42/100
1099/1099 - 2s - loss: 954.5648 - mse: 954.5648 - mae: 24.7958 - val_loss: 890.9953 - val_mse: 890.9953 - val_mae: 23.4350 - 2s/epoch - 2ms/step
Epoch 43/100
1099/1099 - 2s - loss: 954.8863 - mse: 954.8863 - mae: 24.7893 - val_loss: 894.0546 - val_mse: 894.0546 - val_mae: 23.5062 - 2s/epoch - 2ms/step
Epoch 44/100
1099/1099 - 2s - loss: 954.4087 - mse: 954.4087 - mae: 24.7745 - val_loss: 891.4577 - val_mse: 891.4577 - val_mae: 23.4812 - 2s/epoch - 2ms/step
Epoch 45/100
1099/1099 - 2s - loss: 953.3613 - mse: 953.3613 - mae: 24.7946 - val_loss: 889.6320 - val_mse: 889.6320 - val_mae: 23.3639 - 2s/epoch - 2ms/step
Epoch 46/100
1099/1099 - 2s - loss: 954.9649 - mse: 954.9649 - mae: 24.7896 - val_loss: 892.5333 - val_mse: 892.5333 - val_mae: 23.4746 - 2s/epoch - 2ms/step
Epoch 47/100
1099/1099 - 2s - loss: 953.5874 - mse: 953.5874 - mae: 24.7586 - val_loss: 889.2858 - val_mse: 889.2858 - val_mae: 23.3989 - 2s/epoch - 2ms/step
Epoch 48/100
1099/1099 - 2s - loss: 952.6707 - mse: 952.6707 - mae: 24.7429 - val_loss: 892.0638 - val_mse: 892.0638 - val_mae: 23.4307 - 2s/epoch - 2ms/step
Epoch 49/100
1099/1099 - 2s - loss: 951.7842 - mse: 951.7842 - mae: 24.7297 - val_loss: 890.6095 - val_mse: 890.6095 - val_mae: 23.4229 - 2s/epoch - 2ms/step
Epoch 50/100
1099/1099 - 2s - loss: 948.7783 - mse: 948.7783 - mae: 24.6667 - val_loss: 886.4965 - val_mse: 886.4965 - val_mae: 23.3330 - 2s/epoch - 2ms/step
Epoch 51/100
1099/1099 - 2s - loss: 952.1193 - mse: 952.1193 - mae: 24.7293 - val_loss: 888.7664 - val_mse: 888.7664 - val_mae: 23.3293 - 2s/epoch - 2ms/step
Epoch 52/100
1099/1099 - 2s - loss: 950.1282 - mse: 950.1282 - mae: 24.7053 - val_loss: 887.4489 - val_mse: 887.4489 - val_mae: 23.3569 - 2s/epoch - 2ms/step
Epoch 53/100
1099/1099 - 2s - loss: 951.1987 - mse: 951.1987 - mae: 24.6988 - val_loss: 890.6138 - val_mse: 890.6138 - val_mae: 23.4464 - 2s/epoch - 2ms/step
Epoch 54/100
1099/1099 - 2s - loss: 950.5886 - mse: 950.5886 - mae: 24.6892 - val_loss: 888.7913 - val_mse: 888.7913 - val_mae: 23.4049 - 2s/epoch - 2ms/step
Epoch 55/100
1099/1099 - 2s - loss: 949.2623 - mse: 949.2623 - mae: 24.6894 - val_loss: 884.3528 - val_mse: 884.3528 - val_mae: 23.2614 - 2s/epoch - 2ms/step
Epoch 56/100
1099/1099 - 2s - loss: 950.9664 - mse: 950.9664 - mae: 24.6925 - val_loss: 882.9481 - val_mse: 882.9481 - val_mae: 23.1884 - 2s/epoch - 2ms/step
Epoch 57/100
1099/1099 - 2s - loss: 949.0569 - mse: 949.0569 - mae: 24.6633 - val_loss: 885.0074 - val_mse: 885.0074 - val_mae: 23.2932 - 2s/epoch - 2ms/step
Epoch 58/100
1099/1099 - 2s - loss: 947.9716 - mse: 947.9716 - mae: 24.6648 - val_loss: 885.3736 - val_mse: 885.3736 - val_mae: 23.3160 - 2s/epoch - 2ms/step
Epoch 59/100
1099/1099 - 2s - loss: 948.3924 - mse: 948.3924 - mae: 24.6706 - val_loss: 884.7206 - val_mse: 884.7206 - val_mae: 23.2717 - 2s/epoch - 2ms/step
Epoch 60/100
1099/1099 - 2s - loss: 949.7991 - mse: 949.7991 - mae: 24.6678 - val_loss: 887.0705 - val_mse: 887.0705 - val_mae: 23.3330 - 2s/epoch - 2ms/step
Epoch 61/100
1099/1099 - 2s - loss: 947.2445 - mse: 947.2445 - mae: 24.6365 - val_loss:

884.7155 - val_mse: 884.7155 - val_mae: 23.3074 - 2s/epoch - 2ms/step
Epoch 62/100
1099/1099 - 2s - loss: 947.1879 - mse: 947.1879 - mae: 24.6420 - val_loss:
881.6384 - val_mse: 881.6384 - val_mae: 23.2374 - 2s/epoch - 2ms/step
Epoch 63/100
1099/1099 - 2s - loss: 947.6479 - mse: 947.6479 - mae: 24.6352 - val_loss:
882.3479 - val_mse: 882.3479 - val_mae: 23.2013 - 2s/epoch - 2ms/step
Epoch 64/100
1099/1099 - 2s - loss: 946.1750 - mse: 946.1750 - mae: 24.6163 - val_loss:
881.3081 - val_mse: 881.3081 - val_mae: 23.2356 - 2s/epoch - 2ms/step
Epoch 65/100
1099/1099 - 2s - loss: 946.4178 - mse: 946.4178 - mae: 24.6042 - val_loss:
880.5952 - val_mse: 880.5952 - val_mae: 23.1753 - 2s/epoch - 2ms/step
Epoch 66/100
1099/1099 - 2s - loss: 946.8653 - mse: 946.8653 - mae: 24.6192 - val_loss:
880.2178 - val_mse: 880.2178 - val_mae: 23.1703 - 2s/epoch - 2ms/step
Epoch 67/100
1099/1099 - 2s - loss: 944.3074 - mse: 944.3074 - mae: 24.5858 - val_loss:
879.6168 - val_mse: 879.6168 - val_mae: 23.1732 - 2s/epoch - 2ms/step
Epoch 68/100
1099/1099 - 2s - loss: 946.1509 - mse: 946.1509 - mae: 24.5977 - val_loss:
879.8741 - val_mse: 879.8741 - val_mae: 23.1681 - 2s/epoch - 2ms/step
Epoch 69/100
1099/1099 - 2s - loss: 945.4121 - mse: 945.4121 - mae: 24.6047 - val_loss:
880.7360 - val_mse: 880.7360 - val_mae: 23.1821 - 2s/epoch - 2ms/step
Epoch 70/100
1099/1099 - 2s - loss: 946.1823 - mse: 946.1823 - mae: 24.6035 - val_loss:
880.7427 - val_mse: 880.7427 - val_mae: 23.2038 - 2s/epoch - 2ms/step
Epoch 71/100
1099/1099 - 2s - loss: 946.4646 - mse: 946.4646 - mae: 24.6111 - val_loss:
882.5370 - val_mse: 882.5370 - val_mae: 23.3179 - 2s/epoch - 2ms/step
Epoch 72/100
1099/1099 - 2s - loss: 942.2028 - mse: 942.2028 - mae: 24.5477 - val_loss:
879.2086 - val_mse: 879.2086 - val_mae: 23.1718 - 2s/epoch - 2ms/step
Epoch 73/100
1099/1099 - 2s - loss: 944.8148 - mse: 944.8148 - mae: 24.5687 - val_loss:
876.7322 - val_mse: 876.7322 - val_mae: 23.1387 - 2s/epoch - 2ms/step
Epoch 74/100
1099/1099 - 2s - loss: 945.7991 - mse: 945.7991 - mae: 24.6065 - val_loss:
878.8499 - val_mse: 878.8499 - val_mae: 23.1376 - 2s/epoch - 2ms/step
Epoch 75/100
1099/1099 - 2s - loss: 944.0353 - mse: 944.0353 - mae: 24.5748 - val_loss:
880.8234 - val_mse: 880.8234 - val_mae: 23.1810 - 2s/epoch - 2ms/step
Epoch 76/100
1099/1099 - 2s - loss: 944.0222 - mse: 944.0222 - mae: 24.5653 - val_loss:
878.8048 - val_mse: 878.8048 - val_mae: 23.1392 - 2s/epoch - 2ms/step
Epoch 77/100
1099/1099 - 2s - loss: 943.0704 - mse: 943.0704 - mae: 24.5515 - val_loss:
876.2884 - val_mse: 876.2884 - val_mae: 23.0766 - 2s/epoch - 2ms/step
Epoch 78/100
1099/1099 - 2s - loss: 941.3682 - mse: 941.3682 - mae: 24.5126 - val_loss:
876.2550 - val_mse: 876.2550 - val_mae: 23.0912 - 2s/epoch - 2ms/step
Epoch 79/100
1099/1099 - 2s - loss: 945.4991 - mse: 945.4991 - mae: 24.5790 - val_loss:
880.7974 - val_mse: 880.7974 - val_mae: 23.2276 - 2s/epoch - 2ms/step
Epoch 80/100
1099/1099 - 2s - loss: 941.1826 - mse: 941.1826 - mae: 24.5191 - val_loss:
877.2415 - val_mse: 877.2415 - val_mae: 23.1184 - 2s/epoch - 2ms/step
Epoch 81/100
1099/1099 - 2s - loss: 940.7935 - mse: 940.7935 - mae: 24.5013 - val_loss:
876.9792 - val_mse: 876.9792 - val_mae: 23.0946 - 2s/epoch - 2ms/step

Epoch 82/100

1099/1099 - 2s - loss: 943.4091 - mse: 943.4091 - mae: 24.5510 - val_loss: 877.1227 - val_mse: 877.1227 - val_mae: 23.0840 - 2s/epoch - 2ms/step

Epoch 83/100

1099/1099 - 2s - loss: 943.4232 - mse: 943.4232 - mae: 24.5506 - val_loss: 875.5141 - val_mse: 875.5141 - val_mae: 23.0515 - 2s/epoch - 2ms/step

Epoch 84/100

1099/1099 - 2s - loss: 942.4769 - mse: 942.4769 - mae: 24.5253 - val_loss: 875.8915 - val_mse: 875.8915 - val_mae: 23.0716 - 2s/epoch - 2ms/step

Epoch 85/100

1099/1099 - 2s - loss: 941.9694 - mse: 941.9694 - mae: 24.5418 - val_loss: 877.7257 - val_mse: 877.7257 - val_mae: 23.0860 - 2s/epoch - 2ms/step

Epoch 86/100

1099/1099 - 2s - loss: 943.0664 - mse: 943.0664 - mae: 24.5434 - val_loss: 875.6288 - val_mse: 875.6288 - val_mae: 23.0809 - 2s/epoch - 2ms/step

Epoch 87/100

1099/1099 - 2s - loss: 941.6983 - mse: 941.6983 - mae: 24.5114 - val_loss: 878.7219 - val_mse: 878.7219 - val_mae: 23.1577 - 2s/epoch - 2ms/step

Epoch 88/100

1099/1099 - 2s - loss: 942.2097 - mse: 942.2097 - mae: 24.5384 - val_loss: 875.9622 - val_mse: 875.9622 - val_mae: 23.0805 - 2s/epoch - 2ms/step

Epoch 89/100

1099/1099 - 2s - loss: 939.5485 - mse: 939.5485 - mae: 24.4854 - val_loss: 874.3881 - val_mse: 874.3881 - val_mae: 23.0132 - 2s/epoch - 2ms/step

Epoch 90/100

1099/1099 - 2s - loss: 940.7151 - mse: 940.7151 - mae: 24.5221 - val_loss: 873.6753 - val_mse: 873.6753 - val_mae: 23.0367 - 2s/epoch - 2ms/step

Epoch 91/100

1099/1099 - 2s - loss: 941.7370 - mse: 941.7370 - mae: 24.5219 - val_loss: 879.1335 - val_mse: 879.1335 - val_mae: 23.1962 - 2s/epoch - 2ms/step

Epoch 92/100

1099/1099 - 2s - loss: 939.4038 - mse: 939.4038 - mae: 24.5107 - val_loss: 874.9245 - val_mse: 874.9245 - val_mae: 23.0703 - 2s/epoch - 2ms/step

Epoch 93/100

1099/1099 - 2s - loss: 941.5411 - mse: 941.5411 - mae: 24.5208 - val_loss: 877.8152 - val_mse: 877.8152 - val_mae: 23.1063 - 2s/epoch - 2ms/step

Epoch 94/100

1099/1099 - 2s - loss: 941.8752 - mse: 941.8752 - mae: 24.5290 - val_loss: 872.8925 - val_mse: 872.8925 - val_mae: 22.9749 - 2s/epoch - 2ms/step

Epoch 95/100

1099/1099 - 2s - loss: 939.4891 - mse: 939.4891 - mae: 24.4901 - val_loss: 873.4078 - val_mse: 873.4078 - val_mae: 23.0350 - 2s/epoch - 2ms/step

Epoch 96/100

1099/1099 - 2s - loss: 940.4275 - mse: 940.4275 - mae: 24.4988 - val_loss: 877.2036 - val_mse: 877.2036 - val_mae: 23.1426 - 2s/epoch - 2ms/step

Epoch 97/100

1099/1099 - 2s - loss: 939.2797 - mse: 939.2797 - mae: 24.4690 - val_loss: 875.8850 - val_mse: 875.8850 - val_mae: 23.0995 - 2s/epoch - 2ms/step

Epoch 98/100

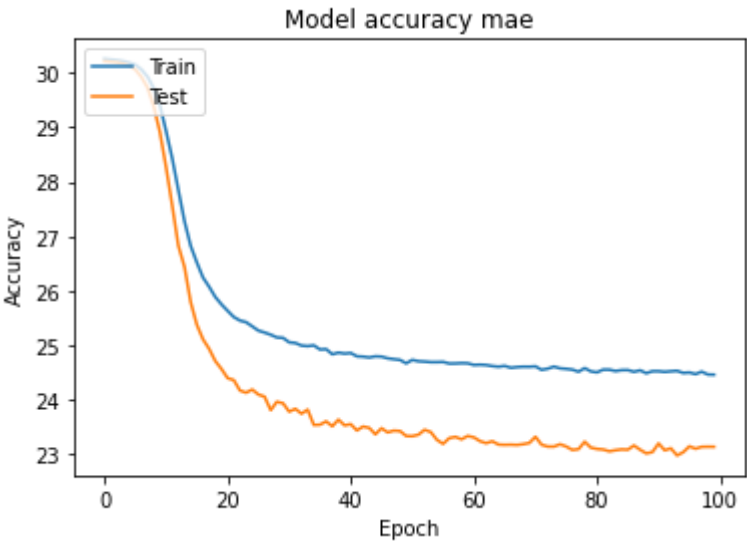
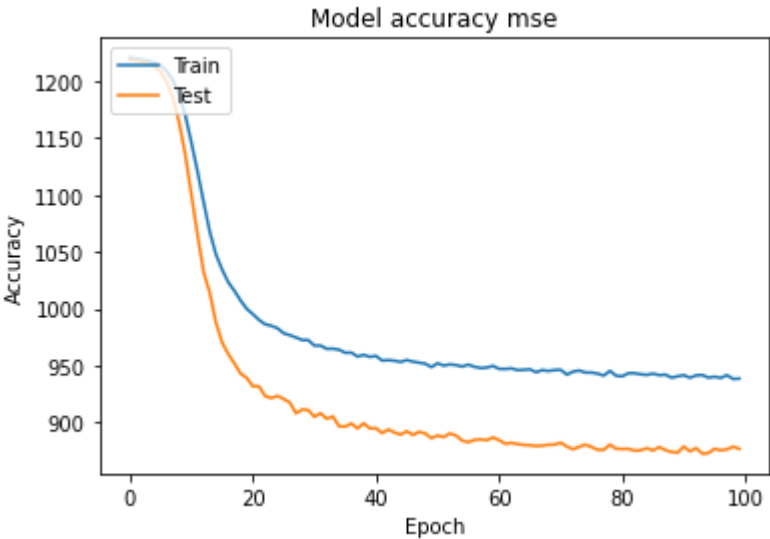
1099/1099 - 2s - loss: 941.7657 - mse: 941.7657 - mae: 24.5137 - val_loss: 876.6512 - val_mse: 876.6512 - val_mae: 23.1333 - 2s/epoch - 2ms/step

Epoch 99/100

1099/1099 - 2s - loss: 938.3690 - mse: 938.3690 - mae: 24.4617 - val_loss: 879.0812 - val_mse: 879.0812 - val_mae: 23.1354 - 2s/epoch - 2ms/step

Epoch 100/100

1099/1099 - 2s - loss: 938.7350 - mse: 938.7350 - mae: 24.4584 - val_loss: 877.1339 - val_mse: 877.1339 - val_mae: 23.1341 - 2s/epoch - 2ms/step



In []:

```
print("Individual phase 1D CNN")

shape=(40,1)
filters=(8,8)
layers=(10,)
epochs = 25
model = create_1d_cnn(shape, True, filters, layers, 'relu')
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse','mae'])

history = model.fit(
    x= x_train_phase, y=y_train,
    validation_data=(x_test_phase, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual phase 1D CNN

Epoch 1/25

1099/1099 - 4s - loss: 1216.2977 - mse: 1216.2977 - mae: 30.1952 - val_loss: 1206.2151 - val_mse: 1206.2151 - val_mae: 30.0357 - 4s/epoch - 4ms/step

Epoch 2/25

1099/1099 - 4s - loss: 1195.4308 - mse: 1195.4308 - mae: 29.8417 - val_loss: 1179.8248 - val_mse: 1179.8248 - val_mae: 29.6378 - 4s/epoch - 3ms/step

Epoch 3/25

1099/1099 - 4s - loss: 1175.6683 - mse: 1175.6683 - mae: 29.4775 - val_loss: 1160.3367 - val_mse: 1160.3367 - val_mae: 29.3408 - 4s/epoch - 3ms/step

Epoch 4/25

1099/1099 - 4s - loss: 1158.2605 - mse: 1158.2605 - mae: 29.1569 - val_loss: 1140.7474 - val_mse: 1140.7474 - val_mae: 29.0244 - 4s/epoch - 3ms/step

Epoch 5/25

1099/1099 - 4s - loss: 1140.7532 - mse: 1140.7532 - mae: 28.8310 - val_loss: 1119.7234 - val_mse: 1119.7234 - val_mae: 28.6858 - 4s/epoch - 3ms/step

Epoch 6/25

1099/1099 - 4s - loss: 1128.0399 - mse: 1128.0399 - mae: 28.5702 - val_loss: 1100.9545 - val_mse: 1100.9545 - val_mae: 28.3654 - 4s/epoch - 3ms/step

Epoch 7/25

1099/1099 - 4s - loss: 1119.0387 - mse: 1119.0387 - mae: 28.3869 - val_loss: 1089.7173 - val_mse: 1089.7173 - val_mae: 28.1668 - 4s/epoch - 3ms/step

Epoch 8/25

1099/1099 - 4s - loss: 1111.0245 - mse: 1111.0245 - mae: 28.2309 - val_loss: 1076.2145 - val_mse: 1076.2145 - val_mae: 27.9422 - 4s/epoch - 3ms/step

Epoch 9/25

1099/1099 - 4s - loss: 1103.7123 - mse: 1103.7123 - mae: 28.0824 - val_loss: 1067.7040 - val_mse: 1067.7040 - val_mae: 27.7685 - 4s/epoch - 3ms/step

Epoch 10/25

1099/1099 - 4s - loss: 1097.7877 - mse: 1097.7877 - mae: 27.9700 - val_loss: 1063.9521 - val_mse: 1063.9521 - val_mae: 27.7054 - 4s/epoch - 3ms/step

Epoch 11/25

1099/1099 - 4s - loss: 1093.1858 - mse: 1093.1858 - mae: 27.8788 - val_loss: 1054.5491 - val_mse: 1054.5491 - val_mae: 27.5408 - 4s/epoch - 3ms/step

Epoch 12/25

1099/1099 - 4s - loss: 1088.0768 - mse: 1088.0768 - mae: 27.7827 - val_loss: 1048.9882 - val_mse: 1048.9882 - val_mae: 27.4138 - 4s/epoch - 3ms/step

Epoch 13/25

1099/1099 - 4s - loss: 1084.5558 - mse: 1084.5558 - mae: 27.7066 - val_loss: 1047.9973 - val_mse: 1047.9973 - val_mae: 27.3853 - 4s/epoch - 3ms/step

Epoch 14/25

1099/1099 - 4s - loss: 1078.5624 - mse: 1078.5624 - mae: 27.5979 - val_loss: 1045.1881 - val_mse: 1045.1881 - val_mae: 27.3135 - 4s/epoch - 3ms/step

Epoch 15/25

1099/1099 - 3s - loss: 1074.0557 - mse: 1074.0557 - mae: 27.4944 - val_loss: 1034.2518 - val_mse: 1034.2518 - val_mae: 27.1242 - 3s/epoch - 3ms/step

Epoch 16/25

1099/1099 - 4s - loss: 1068.6398 - mse: 1068.6398 - mae: 27.3880 - val_loss: 1030.0646 - val_mse: 1030.0646 - val_mae: 27.0366 - 4s/epoch - 3ms/step

Epoch 17/25

1099/1099 - 4s - loss: 1067.2417 - mse: 1067.2417 - mae: 27.3484 - val_loss: 1020.5089 - val_mse: 1020.5089 - val_mae: 26.8578 - 4s/epoch - 3ms/step

Epoch 18/25

1099/1099 - 4s - loss: 1062.6487 - mse: 1062.6487 - mae: 27.2556 - val_loss: 1020.8123 - val_mse: 1020.8123 - val_mae: 26.8413 - 4s/epoch - 3ms/step

Epoch 19/25

1099/1099 - 4s - loss: 1058.0948 - mse: 1058.0948 - mae: 27.1657 - val_loss: 1033.8792 - val_mse: 1033.8792 - val_mae: 27.0302 - 4s/epoch - 3ms/step

Epoch 20/25

1099/1099 - 4s - loss: 1055.1331 - mse: 1055.1331 - mae: 27.1073 - val_loss: 1016.1931 - val_mse: 1016.1931 - val_mae: 26.7217 - 4s/epoch - 4ms/step

Epoch 21/25

1099/1099 - 4s - loss: 1051.9086 - mse: 1051.9086 - mae: 27.0402 - val_loss: 1002.9152 - val_mse: 1002.9152 - val_mae: 26.4843 - 4s/epoch - 3ms/step

Epoch 22/25

1099/1099 - 4s - loss: 1049.3337 - mse: 1049.3337 - mae: 26.9942 - val_loss: 999.9301 - val_mse: 999.9301 - val_mae: 26.4343 - 4s/epoch - 4ms/step

Epoch 23/25

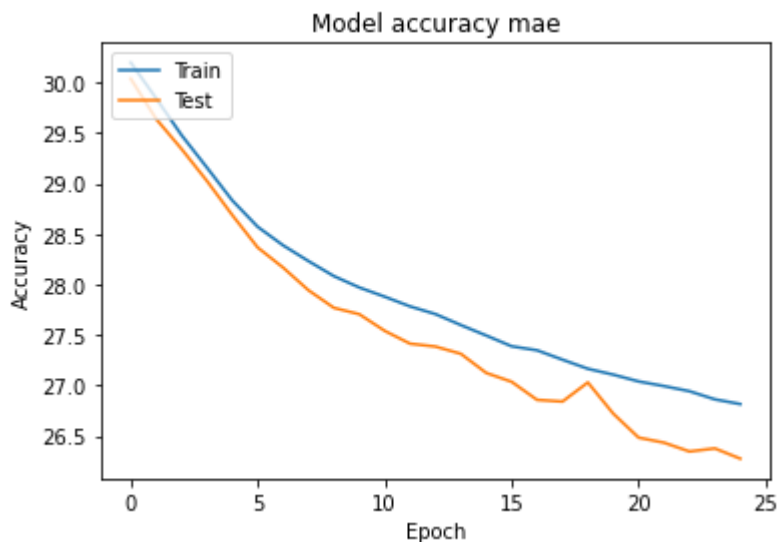
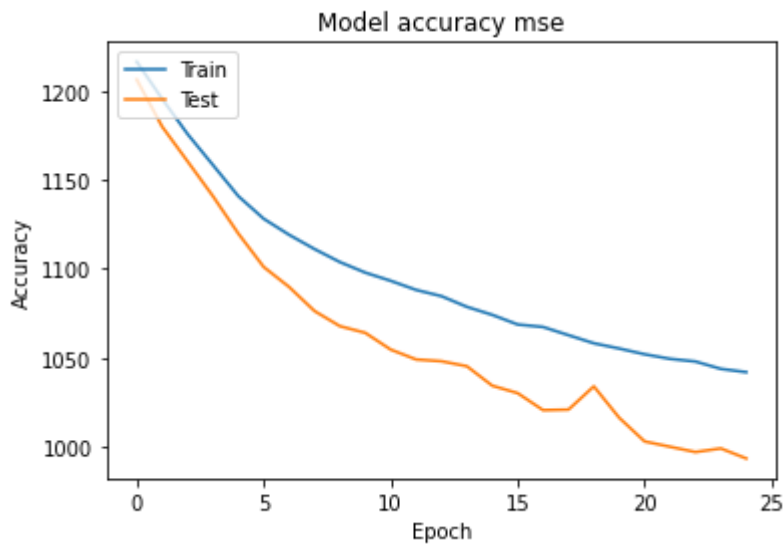
1099/1099 - 4s - loss: 1047.8474 - mse: 1047.8474 - mae: 26.9435 - val_loss: 996.9659 - val_mse: 996.9659 - val_mae: 26.3472 - 4s/epoch - 3ms/step

Epoch 24/25

1099/1099 - 4s - loss: 1043.6991 - mse: 1043.6991 - mae: 26.8629 - val_loss: 998.9954 - val_mse: 998.9954 - val_mae: 26.3775 - 4s/epoch - 3ms/step

Epoch 25/25

1099/1099 - 4s - loss: 1041.8630 - mse: 1041.8630 - mae: 26.8163 - val_loss: 993.3495 - val_mse: 993.3495 - val_mae: 26.2762 - 4s/epoch - 4ms/step



In []:

```
print("Individual magnitude 1D CNN")

shape=(40,1)
filters=(8,8)
layers=(10,)
epochs = 25
model = create_1d_cnn(shape, True, filters, layers, 'relu')
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse','mae'])

history = model.fit(
    x= x_train_magnitude, y=y_train,
    validation_data=(x_test_magnitude, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual magnitude 1D CNN

Epoch 1/25

1099/1099 - 4s - loss: 1210.7852 - mse: 1210.7852 - mae: 30.1071 - val_loss: 1186.9510 - val_mse: 1186.9510 - val_mae: 29.7400 - 4s/epoch - 4ms/step

Epoch 2/25

1099/1099 - 4s - loss: 1166.4862 - mse: 1166.4862 - mae: 29.3029 - val_loss: 1138.8655 - val_mse: 1138.8655 - val_mae: 28.9471 - 4s/epoch - 3ms/step

Epoch 3/25

1099/1099 - 4s - loss: 1135.9924 - mse: 1135.9924 - mae: 28.6577 - val_loss: 1110.5892 - val_mse: 1110.5892 - val_mae: 28.4203 - 4s/epoch - 3ms/step

Epoch 4/25

1099/1099 - 4s - loss: 1112.9933 - mse: 1112.9933 - mae: 28.1892 - val_loss: 1084.3248 - val_mse: 1084.3248 - val_mae: 27.9004 - 4s/epoch - 3ms/step

Epoch 5/25

1099/1099 - 4s - loss: 1098.9187 - mse: 1098.9187 - mae: 27.8932 - val_loss: 1072.3401 - val_mse: 1072.3401 - val_mae: 27.6830 - 4s/epoch - 3ms/step

Epoch 6/25

1099/1099 - 4s - loss: 1084.9713 - mse: 1084.9713 - mae: 27.6437 - val_loss: 1054.3083 - val_mse: 1054.3083 - val_mae: 27.3105 - 4s/epoch - 3ms/step

Epoch 7/25

1099/1099 - 4s - loss: 1075.4646 - mse: 1075.4646 - mae: 27.4469 - val_loss: 1044.3292 - val_mse: 1044.3292 - val_mae: 27.1176 - 4s/epoch - 3ms/step

Epoch 8/25

1099/1099 - 4s - loss: 1064.3057 - mse: 1064.3057 - mae: 27.2430 - val_loss: 1034.9330 - val_mse: 1034.9330 - val_mae: 26.9303 - 4s/epoch - 3ms/step

Epoch 9/25

1099/1099 - 4s - loss: 1059.8121 - mse: 1059.8121 - mae: 27.1309 - val_loss: 1028.7366 - val_mse: 1028.7366 - val_mae: 26.8135 - 4s/epoch - 3ms/step

Epoch 10/25

1099/1099 - 4s - loss: 1051.7070 - mse: 1051.7070 - mae: 26.9629 - val_loss: 1023.9185 - val_mse: 1023.9185 - val_mae: 26.7106 - 4s/epoch - 4ms/step

Epoch 11/25

1099/1099 - 4s - loss: 1047.8878 - mse: 1047.8878 - mae: 26.8787 - val_loss: 1015.1675 - val_mse: 1015.1675 - val_mae: 26.5345 - 4s/epoch - 3ms/step

Epoch 12/25

1099/1099 - 4s - loss: 1042.8966 - mse: 1042.8966 - mae: 26.7659 - val_loss: 1010.2661 - val_mse: 1010.2661 - val_mae: 26.4071 - 4s/epoch - 3ms/step

Epoch 13/25

1099/1099 - 4s - loss: 1040.6500 - mse: 1040.6500 - mae: 26.7304 - val_loss: 1007.9673 - val_mse: 1007.9673 - val_mae: 26.3766 - 4s/epoch - 3ms/step

Epoch 14/25

1099/1099 - 4s - loss: 1036.2032 - mse: 1036.2032 - mae: 26.6237 - val_loss: 1006.1835 - val_mse: 1006.1835 - val_mae: 26.3567 - 4s/epoch - 3ms/step

Epoch 15/25

1099/1099 - 4s - loss: 1033.1619 - mse: 1033.1619 - mae: 26.5636 - val_loss: 995.7186 - val_mse: 995.7186 - val_mae: 26.1314 - 4s/epoch - 3ms/step

Epoch 16/25

1099/1099 - 4s - loss: 1032.3114 - mse: 1032.3114 - mae: 26.5370 - val_loss: 996.2831 - val_mse: 996.2831 - val_mae: 26.1594 - 4s/epoch - 4ms/step

Epoch 17/25

1099/1099 - 3s - loss: 1026.7379 - mse: 1026.7379 - mae: 26.4449 - val_loss: 989.8954 - val_mse: 989.8954 - val_mae: 26.0118 - 3s/epoch - 3ms/step

Epoch 18/25

1099/1099 - 4s - loss: 1024.9189 - mse: 1024.9189 - mae: 26.4031 - val_loss: 990.7425 - val_mse: 990.7425 - val_mae: 26.0179 - 4s/epoch - 3ms/step

Epoch 19/25

1099/1099 - 4s - loss: 1023.7684 - mse: 1023.7684 - mae: 26.3779 - val_loss: 984.1331 - val_mse: 984.1331 - val_mae: 25.8778 - 4s/epoch - 3ms/step

Epoch 20/25

1099/1099 - 4s - loss: 1022.0311 - mse: 1022.0311 - mae: 26.3348 - val_loss: 981.1514 - val_mse: 981.1514 - val_mae: 25.8071 - 4s/epoch - 3ms/step

Epoch 21/25

1099/1099 - 4s - loss: 1020.1183 - mse: 1020.1183 - mae: 26.3000 - val_loss: 977.3129 - val_mse: 977.3129 - val_mae: 25.7120 - 4s/epoch - 3ms/step

Epoch 22/25

1099/1099 - 4s - loss: 1017.6421 - mse: 1017.6421 - mae: 26.2481 - val_loss: 976.5087 - val_mse: 976.5087 - val_mae: 25.7597 - 4s/epoch - 3ms/step

Epoch 23/25

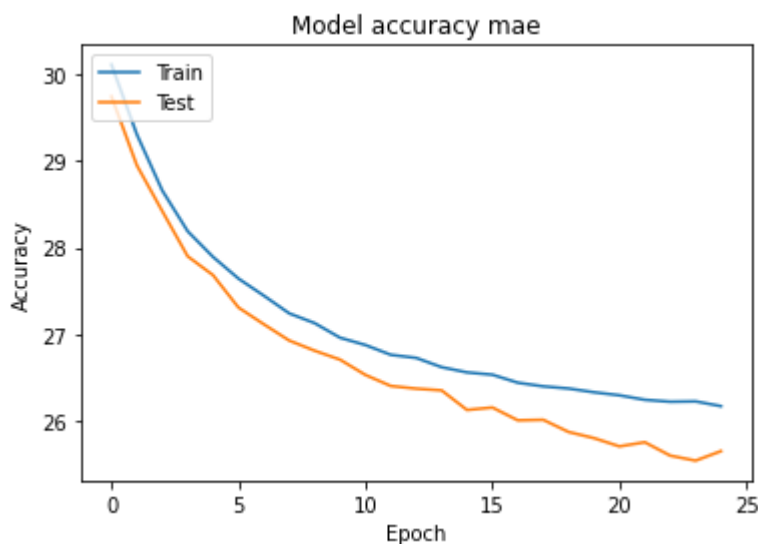
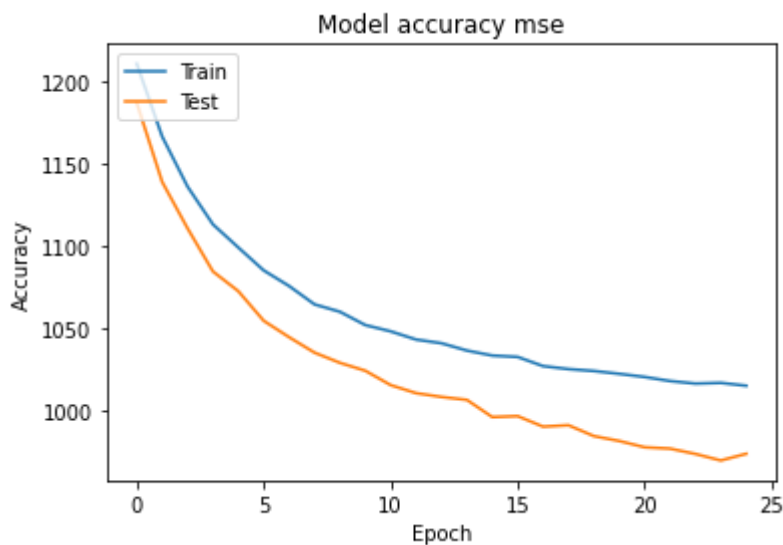
1099/1099 - 4s - loss: 1016.1067 - mse: 1016.1067 - mae: 26.2262 - val_loss: 973.2524 - val_mse: 973.2524 - val_mae: 25.6055 - 4s/epoch - 4ms/step

Epoch 24/25

1099/1099 - 3s - loss: 1016.5273 - mse: 1016.5273 - mae: 26.2300 - val_loss: 969.2855 - val_mse: 969.2855 - val_mae: 25.5477 - 3s/epoch - 3ms/step

Epoch 25/25

1099/1099 - 3s - loss: 1014.7859 - mse: 1014.7859 - mae: 26.1751 - val_loss: 973.3564 - val_mse: 973.3564 - val_mae: 25.6573 - 3s/epoch - 3ms/step



8-by-8 antenna array with PCA

In []:

```
antenna_num = 8

magnitude = pd.read_csv('/content/drive/MyDrive/train_magnitude_8.csv', header=None).to_numpy()
output_data = pd.read_csv('/content/drive/MyDrive/train_outputs_8.csv', header=None).to_numpy()
phase = pd.read_csv('/content/drive/MyDrive/train_phase_8.csv', header=None).to_numpy()

data = load_data(phase, magnitude, output_data, antenna_num)

phase_data = data[0]
magnitude_data = data[1]
output_data = data[2]

reduced_data = perform_dimensionality_reduction(phase_data, magnitude_data)
phase_data = reduced_data[0]
magnitude_data = reduced_data[1]

data_split = split_test_train(phase_data, magnitude_data, output_data, 0.4)
x_train_magnitude = data_split[0]
x_test_magnitude = data_split[1]
x_train_phase = data_split[2]
x_test_phase = data_split[3]
y_train = data_split[4][:,0:2]
y_test = data_split[5][:,0:2]

lr = 0.001
epochs = 100
opt = Adam(learning_rate=lr)
```

In []:

```
print("Combined phase and magnitude MLP")

layers = (640,200,10)
shape = (640,)
magnitude = create_mlp(shape, layers, False, "relu")
phase = create_mlp(shape, layers, False, "relu")

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x=[x_train_magnitude, x_train_phase], y=y_train,
    validation_data=([x_test_magnitude, x_test_phase], y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Combined phase and magnitude MLP

Epoch 1/100

1099/1099 - 8s - loss: 1025.8845 - mse: 1025.8845 - mae: 26.3647 - val_loss: 860.5344 - val_mse: 860.5344 - val_mae: 23.0070 - 8s/epoch - 7ms/step

Epoch 2/100

1099/1099 - 8s - loss: 876.2734 - mse: 876.2734 - mae: 23.1473 - val_loss: 852.1421 - val_mse: 852.1421 - val_mae: 22.8335 - 8s/epoch - 7ms/step

Epoch 3/100

1099/1099 - 7s - loss: 846.9422 - mse: 846.9422 - mae: 22.3413 - val_loss: 843.7009 - val_mse: 843.7009 - val_mae: 22.6507 - 7s/epoch - 6ms/step

Epoch 4/100

1099/1099 - 7s - loss: 835.0092 - mse: 835.0092 - mae: 22.0495 - val_loss: 849.3528 - val_mse: 849.3528 - val_mae: 22.9229 - 7s/epoch - 6ms/step

Epoch 5/100

1099/1099 - 7s - loss: 826.4042 - mse: 826.4042 - mae: 21.8098 - val_loss: 834.4601 - val_mse: 834.4601 - val_mae: 22.4222 - 7s/epoch - 6ms/step

Epoch 6/100

1099/1099 - 7s - loss: 821.1435 - mse: 821.1435 - mae: 21.6660 - val_loss: 829.2800 - val_mse: 829.2800 - val_mae: 22.2604 - 7s/epoch - 6ms/step

Epoch 7/100

1099/1099 - 7s - loss: 816.1537 - mse: 816.1537 - mae: 21.5031 - val_loss: 838.6365 - val_mse: 838.6365 - val_mae: 22.6330 - 7s/epoch - 6ms/step

Epoch 8/100

1099/1099 - 7s - loss: 812.0576 - mse: 812.0576 - mae: 21.3973 - val_loss: 827.7070 - val_mse: 827.7070 - val_mae: 22.2604 - 7s/epoch - 6ms/step

Epoch 9/100

1099/1099 - 7s - loss: 808.9550 - mse: 808.9550 - mae: 21.2999 - val_loss: 831.9583 - val_mse: 831.9583 - val_mae: 22.4271 - 7s/epoch - 6ms/step

Epoch 10/100

1099/1099 - 7s - loss: 805.8104 - mse: 805.8104 - mae: 21.1862 - val_loss: 829.0346 - val_mse: 829.0346 - val_mae: 22.3559 - 7s/epoch - 6ms/step

Epoch 11/100

1099/1099 - 7s - loss: 800.9422 - mse: 800.9422 - mae: 21.0747 - val_loss: 822.9945 - val_mse: 822.9945 - val_mae: 22.1550 - 7s/epoch - 6ms/step

Epoch 12/100

1099/1099 - 7s - loss: 797.2952 - mse: 797.2952 - mae: 20.9703 - val_loss: 833.0017 - val_mse: 833.0017 - val_mae: 22.5561 - 7s/epoch - 6ms/step

Epoch 13/100

1099/1099 - 7s - loss: 794.8323 - mse: 794.8323 - mae: 20.8793 - val_loss: 817.4523 - val_mse: 817.4523 - val_mae: 21.9515 - 7s/epoch - 6ms/step

Epoch 14/100

1099/1099 - 8s - loss: 791.3970 - mse: 791.3970 - mae: 20.8151 - val_loss: 824.9724 - val_mse: 824.9724 - val_mae: 22.2820 - 8s/epoch - 7ms/step

Epoch 15/100

1099/1099 - 7s - loss: 789.8209 - mse: 789.8209 - mae: 20.7675 - val_loss: 818.7377 - val_mse: 818.7377 - val_mae: 22.0845 - 7s/epoch - 6ms/step

Epoch 16/100

1099/1099 - 7s - loss: 786.3016 - mse: 786.3016 - mae: 20.6647 - val_loss: 815.8808 - val_mse: 815.8808 - val_mae: 21.9899 - 7s/epoch - 6ms/step

Epoch 17/100

1099/1099 - 7s - loss: 785.7094 - mse: 785.7094 - mae: 20.6233 - val_loss: 814.8354 - val_mse: 814.8354 - val_mae: 21.8395 - 7s/epoch - 6ms/step

Epoch 18/100

1099/1099 - 7s - loss: 785.0958 - mse: 785.0958 - mae: 20.6353 - val_loss: 818.5073 - val_mse: 818.5073 - val_mae: 21.9378 - 7s/epoch - 6ms/step

Epoch 19/100

1099/1099 - 7s - loss: 782.7697 - mse: 782.7697 - mae: 20.5703 - val_loss: 818.0953 - val_mse: 818.0953 - val_mae: 22.1051 - 7s/epoch - 6ms/step

Epoch 20/100

1099/1099 - 7s - loss: 781.5471 - mse: 781.5471 - mae: 20.5462 - val_loss: 813.0663 - val_mse: 813.0663 - val_mae: 21.7856 - 7s/epoch - 6ms/step

Epoch 21/100

1099/1099 - 7s - loss: 779.5115 - mse: 779.5115 - mae: 20.4960 - val_loss: 810.7053 - val_mse: 810.7053 - val_mae: 21.8801 - 7s/epoch - 6ms/step

Epoch 22/100

1099/1099 - 7s - loss: 777.1675 - mse: 777.1675 - mae: 20.4703 - val_loss: 809.2792 - val_mse: 809.2792 - val_mae: 21.6429 - 7s/epoch - 6ms/step

Epoch 23/100

1099/1099 - 7s - loss: 775.6639 - mse: 775.6639 - mae: 20.4203 - val_loss: 811.5444 - val_mse: 811.5444 - val_mae: 21.9053 - 7s/epoch - 6ms/step

Epoch 24/100

1099/1099 - 7s - loss: 773.3489 - mse: 773.3489 - mae: 20.3590 - val_loss: 803.9655 - val_mse: 803.9655 - val_mae: 21.5631 - 7s/epoch - 6ms/step

Epoch 25/100

1099/1099 - 7s - loss: 771.5883 - mse: 771.5883 - mae: 20.3278 - val_loss: 799.1712 - val_mse: 799.1712 - val_mae: 21.4016 - 7s/epoch - 6ms/step

Epoch 26/100

1099/1099 - 7s - loss: 770.9563 - mse: 770.9563 - mae: 20.3062 - val_loss: 802.9072 - val_mse: 802.9072 - val_mae: 21.5045 - 7s/epoch - 6ms/step

Epoch 27/100

1099/1099 - 7s - loss: 769.6609 - mse: 769.6609 - mae: 20.2887 - val_loss: 816.1434 - val_mse: 816.1434 - val_mae: 21.9764 - 7s/epoch - 6ms/step

Epoch 28/100

1099/1099 - 7s - loss: 768.1417 - mse: 768.1417 - mae: 20.2516 - val_loss: 810.2683 - val_mse: 810.2683 - val_mae: 21.8122 - 7s/epoch - 6ms/step

Epoch 29/100

1099/1099 - 7s - loss: 765.9244 - mse: 765.9244 - mae: 20.2090 - val_loss: 813.8525 - val_mse: 813.8525 - val_mae: 21.9424 - 7s/epoch - 6ms/step

Epoch 30/100

1099/1099 - 7s - loss: 764.7441 - mse: 764.7441 - mae: 20.2096 - val_loss: 809.5757 - val_mse: 809.5757 - val_mae: 21.8061 - 7s/epoch - 6ms/step

Epoch 31/100

1099/1099 - 8s - loss: 761.4522 - mse: 761.4522 - mae: 20.1323 - val_loss: 801.2807 - val_mse: 801.2807 - val_mae: 21.5547 - 8s/epoch - 7ms/step

Epoch 32/100

1099/1099 - 7s - loss: 758.6748 - mse: 758.6748 - mae: 20.1156 - val_loss: 796.3807 - val_mse: 796.3807 - val_mae: 21.3459 - 7s/epoch - 6ms/step

Epoch 33/100

1099/1099 - 7s - loss: 760.3474 - mse: 760.3474 - mae: 20.1208 - val_loss: 800.5594 - val_mse: 800.5594 - val_mae: 21.6158 - 7s/epoch - 6ms/step

Epoch 34/100

1099/1099 - 7s - loss: 755.6483 - mse: 755.6483 - mae: 20.0590 - val_loss: 812.1188 - val_mse: 812.1188 - val_mae: 21.9890 - 7s/epoch - 6ms/step

Epoch 35/100

1099/1099 - 7s - loss: 753.1369 - mse: 753.1369 - mae: 20.0372 - val_loss: 804.3508 - val_mse: 804.3508 - val_mae: 21.8064 - 7s/epoch - 6ms/step

Epoch 36/100

1099/1099 - 8s - loss: 750.9350 - mse: 750.9350 - mae: 20.0091 - val_loss: 797.6609 - val_mse: 797.6609 - val_mae: 21.5277 - 8s/epoch - 7ms/step

Epoch 37/100

1099/1099 - 7s - loss: 746.4983 - mse: 746.4983 - mae: 19.9119 - val_loss: 793.3553 - val_mse: 793.3553 - val_mae: 21.4291 - 7s/epoch - 6ms/step

Epoch 38/100

1099/1099 - 9s - loss: 743.8789 - mse: 743.8789 - mae: 19.8145 - val_loss: 772.0070 - val_mse: 772.0070 - val_mae: 20.5377 - 9s/epoch - 8ms/step

Epoch 39/100

1099/1099 - 9s - loss: 738.4293 - mse: 738.4293 - mae: 19.7274 - val_loss: 790.0647 - val_mse: 790.0647 - val_mae: 21.3691 - 9s/epoch - 9ms/step

Epoch 40/100

1099/1099 - 8s - loss: 739.4080 - mse: 739.4080 - mae: 19.7258 - val_loss: 783.8575 - val_mse: 783.8575 - val_mae: 21.2579 - 8s/epoch - 7ms/step

Epoch 41/100

1099/1099 - 7s - loss: 730.7934 - mse: 730.7934 - mae: 19.5820 - val_loss: 775.6956 - val_mse: 775.6956 - val_mae: 20.7860 - 7s/epoch - 6ms/step
Epoch 42/100
1099/1099 - 7s - loss: 727.9866 - mse: 727.9866 - mae: 19.4986 - val_loss: 779.9856 - val_mse: 779.9856 - val_mae: 21.0884 - 7s/epoch - 6ms/step
Epoch 43/100
1099/1099 - 8s - loss: 721.3734 - mse: 721.3734 - mae: 19.3878 - val_loss: 767.3196 - val_mse: 767.3196 - val_mae: 20.6042 - 8s/epoch - 7ms/step
Epoch 44/100
1099/1099 - 7s - loss: 715.1903 - mse: 715.1903 - mae: 19.2783 - val_loss: 775.8339 - val_mse: 775.8339 - val_mae: 21.0571 - 7s/epoch - 6ms/step
Epoch 45/100
1099/1099 - 7s - loss: 709.3163 - mse: 709.3163 - mae: 19.1585 - val_loss: 772.2623 - val_mse: 772.2623 - val_mae: 20.9427 - 7s/epoch - 6ms/step
Epoch 46/100
1099/1099 - 7s - loss: 707.0966 - mse: 707.0966 - mae: 19.1493 - val_loss: 766.2667 - val_mse: 766.2667 - val_mae: 20.7929 - 7s/epoch - 6ms/step
Epoch 47/100
1099/1099 - 8s - loss: 698.6447 - mse: 698.6447 - mae: 18.9832 - val_loss: 742.4350 - val_mse: 742.4350 - val_mae: 19.8385 - 8s/epoch - 7ms/step
Epoch 48/100
1099/1099 - 7s - loss: 693.6639 - mse: 693.6639 - mae: 18.8814 - val_loss: 750.3629 - val_mse: 750.3629 - val_mae: 20.3550 - 7s/epoch - 6ms/step
Epoch 49/100
1099/1099 - 7s - loss: 693.3871 - mse: 693.3871 - mae: 18.8614 - val_loss: 742.9944 - val_mse: 742.9944 - val_mae: 20.2032 - 7s/epoch - 6ms/step
Epoch 50/100
1099/1099 - 7s - loss: 684.1479 - mse: 684.1479 - mae: 18.6613 - val_loss: 735.1847 - val_mse: 735.1847 - val_mae: 19.7983 - 7s/epoch - 6ms/step
Epoch 51/100
1099/1099 - 7s - loss: 679.1394 - mse: 679.1394 - mae: 18.5591 - val_loss: 737.7299 - val_mse: 737.7299 - val_mae: 20.1205 - 7s/epoch - 6ms/step
Epoch 52/100
1099/1099 - 7s - loss: 665.3412 - mse: 665.3412 - mae: 18.2989 - val_loss: 731.2357 - val_mse: 731.2357 - val_mae: 19.8962 - 7s/epoch - 6ms/step
Epoch 53/100
1099/1099 - 7s - loss: 661.4922 - mse: 661.4922 - mae: 18.1774 - val_loss: 720.5526 - val_mse: 720.5526 - val_mae: 19.4875 - 7s/epoch - 6ms/step
Epoch 54/100
1099/1099 - 8s - loss: 652.5436 - mse: 652.5436 - mae: 18.0079 - val_loss: 715.1393 - val_mse: 715.1393 - val_mae: 19.3686 - 8s/epoch - 7ms/step
Epoch 55/100
1099/1099 - 8s - loss: 646.8547 - mse: 646.8547 - mae: 17.8778 - val_loss: 710.4789 - val_mse: 710.4789 - val_mae: 19.5264 - 8s/epoch - 7ms/step
Epoch 56/100
1099/1099 - 7s - loss: 641.8643 - mse: 641.8643 - mae: 17.7833 - val_loss: 707.0818 - val_mse: 707.0818 - val_mae: 19.3535 - 7s/epoch - 6ms/step
Epoch 57/100
1099/1099 - 7s - loss: 634.0418 - mse: 634.0418 - mae: 17.6418 - val_loss: 699.3821 - val_mse: 699.3821 - val_mae: 19.1127 - 7s/epoch - 6ms/step
Epoch 58/100
1099/1099 - 7s - loss: 629.0936 - mse: 629.0936 - mae: 17.5523 - val_loss: 698.7074 - val_mse: 698.7074 - val_mae: 19.0814 - 7s/epoch - 7ms/step
Epoch 59/100
1099/1099 - 7s - loss: 622.4538 - mse: 622.4538 - mae: 17.4499 - val_loss: 691.8526 - val_mse: 691.8526 - val_mae: 19.0826 - 7s/epoch - 7ms/step
Epoch 60/100
1099/1099 - 7s - loss: 614.0702 - mse: 614.0702 - mae: 17.2856 - val_loss: 688.8848 - val_mse: 688.8848 - val_mae: 18.7554 - 7s/epoch - 7ms/step
Epoch 61/100
1099/1099 - 7s - loss: 607.9694 - mse: 607.9694 - mae: 17.1596 - val_loss:

681.8370 - val_mse: 681.8370 - val_mae: 18.5252 - 7s/epoch - 7ms/step
Epoch 62/100
1099/1099 - 8s - loss: 604.3333 - mse: 604.3333 - mae: 17.0881 - val_loss:
674.3210 - val_mse: 674.3210 - val_mae: 18.3855 - 8s/epoch - 7ms/step
Epoch 63/100
1099/1099 - 7s - loss: 599.9025 - mse: 599.9025 - mae: 16.9817 - val_loss:
681.8011 - val_mse: 681.8011 - val_mae: 18.6426 - 7s/epoch - 6ms/step
Epoch 64/100
1099/1099 - 7s - loss: 593.6049 - mse: 593.6049 - mae: 16.8532 - val_loss:
676.9088 - val_mse: 676.9088 - val_mae: 18.2682 - 7s/epoch - 6ms/step
Epoch 65/100
1099/1099 - 7s - loss: 587.5930 - mse: 587.5930 - mae: 16.7037 - val_loss:
674.3119 - val_mse: 674.3119 - val_mae: 18.4509 - 7s/epoch - 6ms/step
Epoch 66/100
1099/1099 - 7s - loss: 579.5403 - mse: 579.5403 - mae: 16.5531 - val_loss:
675.2411 - val_mse: 675.2411 - val_mae: 18.4297 - 7s/epoch - 6ms/step
Epoch 67/100
1099/1099 - 7s - loss: 577.8235 - mse: 577.8235 - mae: 16.5071 - val_loss:
658.2297 - val_mse: 658.2297 - val_mae: 18.0256 - 7s/epoch - 7ms/step
Epoch 68/100
1099/1099 - 8s - loss: 565.4691 - mse: 565.4691 - mae: 16.2761 - val_loss:
670.2971 - val_mse: 670.2971 - val_mae: 18.0281 - 8s/epoch - 8ms/step
Epoch 69/100
1099/1099 - 7s - loss: 559.6612 - mse: 559.6612 - mae: 16.1864 - val_loss:
662.2804 - val_mse: 662.2804 - val_mae: 17.9449 - 7s/epoch - 6ms/step
Epoch 70/100
1099/1099 - 7s - loss: 555.9463 - mse: 555.9463 - mae: 16.0977 - val_loss:
655.6631 - val_mse: 655.6631 - val_mae: 17.9574 - 7s/epoch - 6ms/step
Epoch 71/100
1099/1099 - 7s - loss: 549.6251 - mse: 549.6251 - mae: 15.9824 - val_loss:
645.2451 - val_mse: 645.2451 - val_mae: 17.7132 - 7s/epoch - 6ms/step
Epoch 72/100
1099/1099 - 7s - loss: 540.8966 - mse: 540.8966 - mae: 15.8072 - val_loss:
645.5848 - val_mse: 645.5848 - val_mae: 17.5527 - 7s/epoch - 6ms/step
Epoch 73/100
1099/1099 - 7s - loss: 538.8939 - mse: 538.8939 - mae: 15.7254 - val_loss:
644.4399 - val_mse: 644.4399 - val_mae: 17.4912 - 7s/epoch - 6ms/step
Epoch 74/100
1099/1099 - 7s - loss: 537.7961 - mse: 537.7961 - mae: 15.7179 - val_loss:
639.7035 - val_mse: 639.7035 - val_mae: 17.3849 - 7s/epoch - 6ms/step
Epoch 75/100
1099/1099 - 7s - loss: 527.5705 - mse: 527.5705 - mae: 15.5244 - val_loss:
640.3400 - val_mse: 640.3400 - val_mae: 17.4052 - 7s/epoch - 6ms/step
Epoch 76/100
1099/1099 - 7s - loss: 524.6198 - mse: 524.6198 - mae: 15.4274 - val_loss:
636.0308 - val_mse: 636.0308 - val_mae: 17.4467 - 7s/epoch - 6ms/step
Epoch 77/100
1099/1099 - 7s - loss: 516.3234 - mse: 516.3234 - mae: 15.3235 - val_loss:
621.3825 - val_mse: 621.3825 - val_mae: 16.8602 - 7s/epoch - 6ms/step
Epoch 78/100
1099/1099 - 7s - loss: 516.1130 - mse: 516.1130 - mae: 15.3269 - val_loss:
623.4585 - val_mse: 623.4585 - val_mae: 16.9583 - 7s/epoch - 6ms/step
Epoch 79/100
1099/1099 - 7s - loss: 508.2280 - mse: 508.2280 - mae: 15.1895 - val_loss:
622.9363 - val_mse: 622.9363 - val_mae: 16.8364 - 7s/epoch - 6ms/step
Epoch 80/100
1099/1099 - 7s - loss: 505.7239 - mse: 505.7239 - mae: 15.0829 - val_loss:
620.4648 - val_mse: 620.4648 - val_mae: 16.5446 - 7s/epoch - 6ms/step
Epoch 81/100
1099/1099 - 7s - loss: 505.6805 - mse: 505.6805 - mae: 15.0828 - val_loss:
628.0810 - val_mse: 628.0810 - val_mae: 16.8947 - 7s/epoch - 6ms/step

Epoch 82/100

1099/1099 - 7s - loss: 493.7125 - mse: 493.7125 - mae: 14.8747 - val_loss: 617.0193 - val_mse: 617.0193 - val_mae: 16.4233 - 7s/epoch - 6ms/step

Epoch 83/100

1099/1099 - 7s - loss: 487.7771 - mse: 487.7771 - mae: 14.7290 - val_loss: 612.0808 - val_mse: 612.0808 - val_mae: 16.6565 - 7s/epoch - 6ms/step

Epoch 84/100

1099/1099 - 8s - loss: 480.7944 - mse: 480.7944 - mae: 14.5593 - val_loss: 612.4272 - val_mse: 612.4272 - val_mae: 16.4068 - 8s/epoch - 7ms/step

Epoch 85/100

1099/1099 - 7s - loss: 477.5635 - mse: 477.5635 - mae: 14.4933 - val_loss: 599.7974 - val_mse: 599.7974 - val_mae: 16.0885 - 7s/epoch - 6ms/step

Epoch 86/100

1099/1099 - 7s - loss: 478.6944 - mse: 478.6944 - mae: 14.4738 - val_loss: 613.9608 - val_mse: 613.9608 - val_mae: 16.3818 - 7s/epoch - 6ms/step

Epoch 87/100

1099/1099 - 7s - loss: 475.4787 - mse: 475.4787 - mae: 14.3997 - val_loss: 605.7756 - val_mse: 605.7756 - val_mae: 16.2429 - 7s/epoch - 6ms/step

Epoch 88/100

1099/1099 - 7s - loss: 467.0253 - mse: 467.0253 - mae: 14.2570 - val_loss: 596.3347 - val_mse: 596.3347 - val_mae: 16.0862 - 7s/epoch - 6ms/step

Epoch 89/100

1099/1099 - 7s - loss: 465.9453 - mse: 465.9453 - mae: 14.2001 - val_loss: 606.7302 - val_mse: 606.7302 - val_mae: 16.3293 - 7s/epoch - 6ms/step

Epoch 90/100

1099/1099 - 8s - loss: 460.3357 - mse: 460.3357 - mae: 14.1082 - val_loss: 597.4281 - val_mse: 597.4281 - val_mae: 16.1328 - 8s/epoch - 8ms/step

Epoch 91/100

1099/1099 - 7s - loss: 461.3975 - mse: 461.3975 - mae: 14.0730 - val_loss: 602.4291 - val_mse: 602.4291 - val_mae: 16.3999 - 7s/epoch - 6ms/step

Epoch 92/100

1099/1099 - 8s - loss: 456.0500 - mse: 456.0500 - mae: 14.0032 - val_loss: 594.4326 - val_mse: 594.4326 - val_mae: 15.9086 - 8s/epoch - 8ms/step

Epoch 93/100

1099/1099 - 7s - loss: 456.7992 - mse: 456.7992 - mae: 14.0348 - val_loss: 595.3022 - val_mse: 595.3022 - val_mae: 15.9599 - 7s/epoch - 7ms/step

Epoch 94/100

1099/1099 - 7s - loss: 445.1946 - mse: 445.1946 - mae: 13.8001 - val_loss: 588.9848 - val_mse: 588.9848 - val_mae: 15.5374 - 7s/epoch - 6ms/step

Epoch 95/100

1099/1099 - 7s - loss: 445.5470 - mse: 445.5470 - mae: 13.7812 - val_loss: 588.5779 - val_mse: 588.5779 - val_mae: 15.6708 - 7s/epoch - 6ms/step

Epoch 96/100

1099/1099 - 7s - loss: 444.6913 - mse: 444.6913 - mae: 13.7648 - val_loss: 602.9775 - val_mse: 602.9775 - val_mae: 16.1747 - 7s/epoch - 6ms/step

Epoch 97/100

1099/1099 - 7s - loss: 439.9096 - mse: 439.9096 - mae: 13.6939 - val_loss: 579.3364 - val_mse: 579.3364 - val_mae: 15.5185 - 7s/epoch - 6ms/step

Epoch 98/100

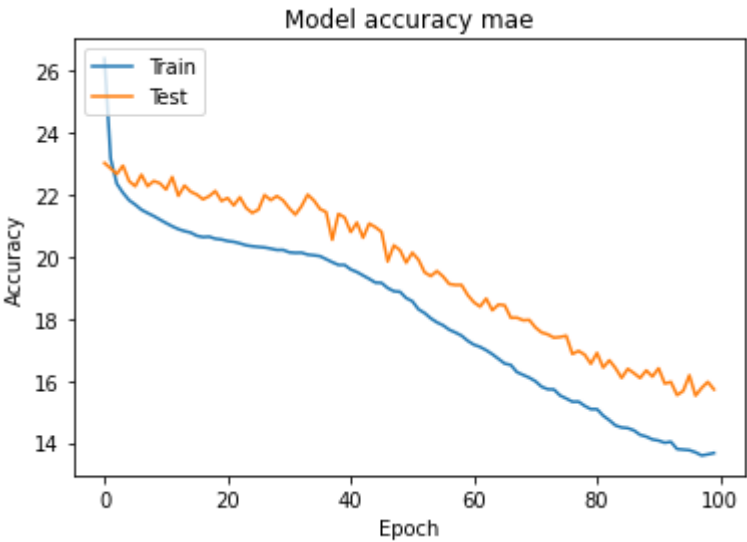
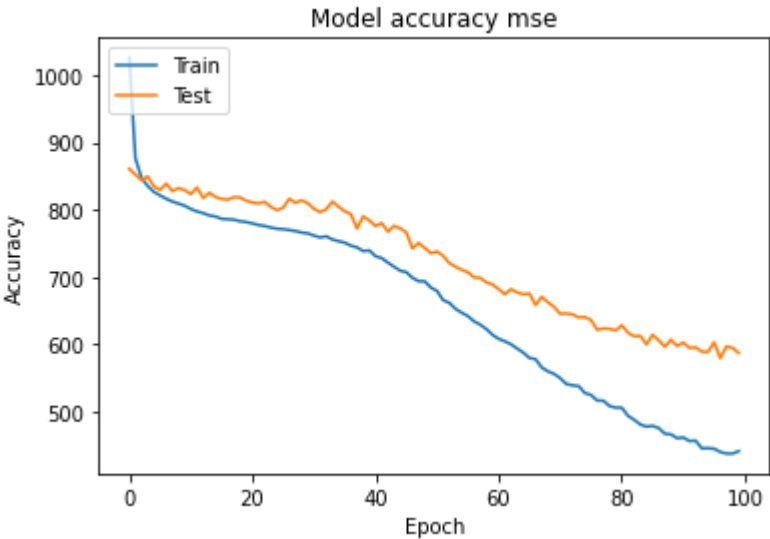
1099/1099 - 7s - loss: 437.5908 - mse: 437.5908 - mae: 13.5929 - val_loss: 596.8997 - val_mse: 596.8997 - val_mae: 15.7673 - 7s/epoch - 6ms/step

Epoch 99/100

1099/1099 - 7s - loss: 437.3941 - mse: 437.3941 - mae: 13.6288 - val_loss: 594.4510 - val_mse: 594.4510 - val_mae: 15.9597 - 7s/epoch - 6ms/step

Epoch 100/100

1099/1099 - 8s - loss: 441.1494 - mse: 441.1494 - mae: 13.6724 - val_loss: 586.9399 - val_mse: 586.9399 - val_mae: 15.7181 - 8s/epoch - 7ms/step



In []:

```
print("Combined phase and magnitude 1D CNN")

shape=(640,1)
filters=(64,64)
layers=(100, )
epochs = 25

phase = create_1d_cnn(shape, False, filters, layers, 'relu')
magnitude = create_1d_cnn(shape, False, filters, layers, 'relu')

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x=[x_train_magnitude, x_train_phase], y=y_train,
    validation_data=(x_test_magnitude, x_test_phase),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Combined phase and magnitude 1D CNN

Epoch 1/25

1099/1099 - 101s - loss: 1140.8313 - mse: 1140.8313 - mae: 28.7379 - val_loss: 1029.0382 - val_mse: 1029.0382 - val_mae: 26.8404 - 101s/epoch - 92ms/step

Epoch 2/25

1099/1099 - 100s - loss: 1040.9501 - mse: 1040.9501 - mae: 26.7759 - val_loss: 946.0192 - val_mse: 946.0192 - val_mae: 25.1969 - 100s/epoch - 91ms/step

Epoch 3/25

1099/1099 - 100s - loss: 951.7106 - mse: 951.7106 - mae: 25.0102 - val_loss: 874.0647 - val_mse: 874.0647 - val_mae: 23.5939 - 100s/epoch - 91ms/step

Epoch 4/25

1099/1099 - 100s - loss: 896.8414 - mse: 896.8414 - mae: 23.8580 - val_loss: 842.1841 - val_mse: 842.1841 - val_mae: 22.8146 - 100s/epoch - 91ms/step

Epoch 5/25

1099/1099 - 99s - loss: 864.7304 - mse: 864.7304 - mae: 23.1422 - val_loss: 814.4605 - val_mse: 814.4605 - val_mae: 22.0407 - 99s/epoch - 90ms/step

Epoch 6/25

1099/1099 - 99s - loss: 841.9850 - mse: 841.9850 - mae: 22.6367 - val_loss: 802.0651 - val_mse: 802.0651 - val_mae: 21.7525 - 99s/epoch - 90ms/step

Epoch 7/25

1099/1099 - 99s - loss: 826.4097 - mse: 826.4097 - mae: 22.2937 - val_loss: 790.7220 - val_mse: 790.7220 - val_mae: 21.3193 - 99s/epoch - 90ms/step

Epoch 8/25

1099/1099 - 99s - loss: 812.1224 - mse: 812.1224 - mae: 21.9984 - val_loss: 792.5168 - val_mse: 792.5168 - val_mae: 21.6252 - 99s/epoch - 90ms/step

Epoch 9/25

1099/1099 - 99s - loss: 799.2000 - mse: 799.2000 - mae: 21.7189 - val_loss: 776.4348 - val_mse: 776.4348 - val_mae: 21.1915 - 99s/epoch - 90ms/step

Epoch 10/25

1099/1099 - 99s - loss: 788.4193 - mse: 788.4193 - mae: 21.5036 - val_loss: 769.4113 - val_mse: 769.4113 - val_mae: 20.9969 - 99s/epoch - 90ms/step

Epoch 11/25

1099/1099 - 103s - loss: 772.0497 - mse: 772.0497 - mae: 21.1913 - val_loss: 747.4145 - val_mse: 747.4145 - val_mae: 20.2334 - 103s/epoch - 94ms/step

p

Epoch 12/25

1099/1099 - 99s - loss: 762.5204 - mse: 762.5204 - mae: 21.0002 - val_loss: 749.5748 - val_mse: 749.5748 - val_mae: 20.6292 - 99s/epoch - 90ms/step

Epoch 13/25

1099/1099 - 99s - loss: 748.0908 - mse: 748.0908 - mae: 20.7188 - val_loss: 736.5612 - val_mse: 736.5612 - val_mae: 20.2216 - 99s/epoch - 90ms/step

Epoch 14/25

1099/1099 - 100s - loss: 736.5002 - mse: 736.5002 - mae: 20.4428 - val_loss: 725.8771 - val_mse: 725.8771 - val_mae: 20.0315 - 100s/epoch - 91ms/step

p

Epoch 15/25

1099/1099 - 99s - loss: 724.8705 - mse: 724.8705 - mae: 20.2323 - val_loss: 713.2191 - val_mse: 713.2191 - val_mae: 19.6466 - 99s/epoch - 90ms/step

Epoch 16/25

1099/1099 - 99s - loss: 713.7825 - mse: 713.7825 - mae: 20.0277 - val_loss: 706.2437 - val_mse: 706.2437 - val_mae: 19.5829 - 99s/epoch - 90ms/step

Epoch 17/25

1099/1099 - 99s - loss: 703.5368 - mse: 703.5368 - mae: 19.8485 - val_loss: 711.0486 - val_mse: 711.0486 - val_mae: 19.7333 - 99s/epoch - 90ms/step

Epoch 18/25

1099/1099 - 100s - loss: 695.2574 - mse: 695.2574 - mae: 19.6429 - val_loss: 697.5905 - val_mse: 697.5905 - val_mae: 19.3943 - 100s/epoch - 91ms/step

p

Epoch 19/25

1099/1099 - 100s - loss: 681.7281 - mse: 681.7281 - mae: 19.3965 - val_loss: 684.9005 - val_mse: 684.9005 - val_mae: 19.2478 - 100s/epoch - 91ms/step

p

Epoch 20/25

1099/1099 - 101s - loss: 667.4342 - mse: 667.4342 - mae: 19.1176 - val_loss: 671.1520 - val_mse: 671.1520 - val_mae: 18.8645 - 101s/epoch - 92ms/step

p

Epoch 21/25

1099/1099 - 99s - loss: 656.0596 - mse: 656.0596 - mae: 18.8956 - val_loss: 670.5555 - val_mse: 670.5555 - val_mae: 18.9461 - 99s/epoch - 90ms/step

Epoch 22/25

1099/1099 - 100s - loss: 646.7770 - mse: 646.7770 - mae: 18.7036 - val_loss: 661.8258 - val_mse: 661.8258 - val_mae: 18.7640 - 100s/epoch - 91ms/step

p

Epoch 23/25

1099/1099 - 101s - loss: 637.2195 - mse: 637.2195 - mae: 18.5072 - val_loss: 651.2854 - val_mse: 651.2854 - val_mae: 18.3906 - 101s/epoch - 91ms/step

p

Epoch 24/25

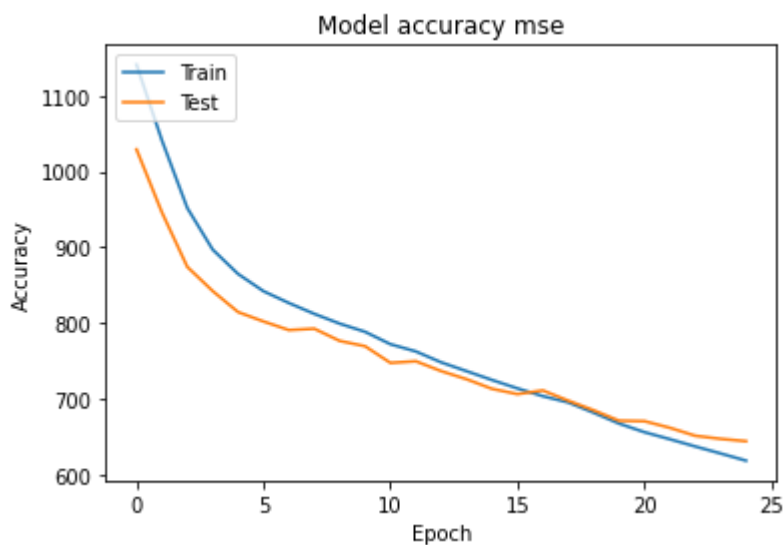
1099/1099 - 100s - loss: 627.9684 - mse: 627.9684 - mae: 18.3386 - val_loss: 647.2165 - val_mse: 647.2165 - val_mae: 18.3084 - 100s/epoch - 91ms/step

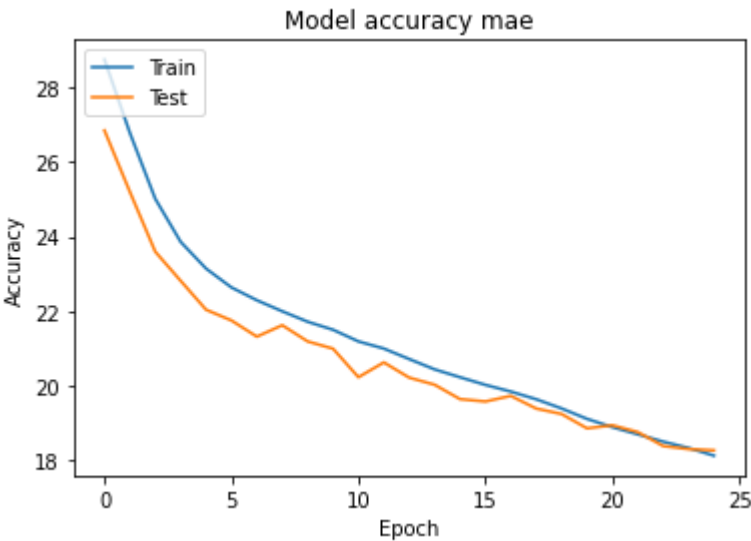
p

Epoch 25/25

1099/1099 - 100s - loss: 618.4814 - mse: 618.4814 - mae: 18.1330 - val_loss: 644.1506 - val_mse: 644.1506 - val_mae: 18.2739 - 100s/epoch - 91ms/step

p





In []:

```
print("Individual phase MLP")

layers = (640,200,10)
shape = (640,)
model = create_mlp(shape, layers, True, "relu")
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])
epochs = 100

history = model.fit(
    x= x_train_phase, y=y_train,
    validation_data=(x_test_phase, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual phase MLP

Epoch 1/100

1099/1099 - 6s - loss: 1220.7804 - mse: 1220.7804 - mae: 30.2662 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 6s/epoch - 5ms/step

Epoch 2/100

1099/1099 - 5s - loss: 1220.5554 - mse: 1220.5554 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 3/100

1099/1099 - 5s - loss: 1220.5768 - mse: 1220.5768 - mae: 30.2630 - val_loss: 1219.1569 - val_mse: 1219.1569 - val_mae: 30.2256 - 5s/epoch - 5ms/step

Epoch 4/100

1099/1099 - 5s - loss: 1135.8419 - mse: 1135.8419 - mae: 28.5509 - val_loss: 884.9274 - val_mse: 884.9274 - val_mae: 23.7844 - 5s/epoch - 5ms/step

Epoch 5/100

1099/1099 - 5s - loss: 956.9708 - mse: 956.9708 - mae: 24.7044 - val_loss: 852.0176 - val_mse: 852.0176 - val_mae: 22.7201 - 5s/epoch - 5ms/step

Epoch 6/100

1099/1099 - 5s - loss: 927.8604 - mse: 927.8604 - mae: 24.0661 - val_loss: 842.0391 - val_mse: 842.0391 - val_mae: 22.5749 - 5s/epoch - 5ms/step

Epoch 7/100

1099/1099 - 5s - loss: 900.5242 - mse: 900.5242 - mae: 23.6530 - val_loss: 821.3241 - val_mse: 821.3241 - val_mae: 21.8421 - 5s/epoch - 5ms/step

Epoch 8/100

1099/1099 - 5s - loss: 886.8402 - mse: 886.8402 - mae: 23.4463 - val_loss: 823.6099 - val_mse: 823.6099 - val_mae: 21.9904 - 5s/epoch - 5ms/step

Epoch 9/100

1099/1099 - 5s - loss: 882.1669 - mse: 882.1669 - mae: 23.3484 - val_loss: 815.8503 - val_mse: 815.8503 - val_mae: 21.6952 - 5s/epoch - 5ms/step

Epoch 10/100

1099/1099 - 5s - loss: 879.0270 - mse: 879.0270 - mae: 23.2725 - val_loss: 816.4920 - val_mse: 816.4920 - val_mae: 21.7678 - 5s/epoch - 5ms/step

Epoch 11/100

1099/1099 - 5s - loss: 878.3541 - mse: 878.3541 - mae: 23.2591 - val_loss: 807.5890 - val_mse: 807.5890 - val_mae: 21.3598 - 5s/epoch - 5ms/step

Epoch 12/100

1099/1099 - 5s - loss: 874.0274 - mse: 874.0274 - mae: 23.1566 - val_loss: 820.7165 - val_mse: 820.7165 - val_mae: 22.0406 - 5s/epoch - 5ms/step

Epoch 13/100

1099/1099 - 5s - loss: 872.4546 - mse: 872.4546 - mae: 23.1306 - val_loss: 803.1486 - val_mse: 803.1486 - val_mae: 21.1797 - 5s/epoch - 5ms/step

Epoch 14/100

1099/1099 - 5s - loss: 870.4610 - mse: 870.4610 - mae: 23.0819 - val_loss: 810.7018 - val_mse: 810.7018 - val_mae: 21.5932 - 5s/epoch - 5ms/step

Epoch 15/100

1099/1099 - 5s - loss: 869.4938 - mse: 869.4938 - mae: 23.0663 - val_loss: 807.8889 - val_mse: 807.8889 - val_mae: 21.5288 - 5s/epoch - 5ms/step

Epoch 16/100

1099/1099 - 5s - loss: 866.0026 - mse: 866.0026 - mae: 22.9905 - val_loss: 807.7624 - val_mse: 807.7624 - val_mae: 21.5468 - 5s/epoch - 5ms/step

Epoch 17/100

1099/1099 - 5s - loss: 864.8858 - mse: 864.8858 - mae: 22.9487 - val_loss: 809.2556 - val_mse: 809.2556 - val_mae: 21.5672 - 5s/epoch - 5ms/step

Epoch 18/100

1099/1099 - 5s - loss: 866.3463 - mse: 866.3463 - mae: 22.9674 - val_loss: 794.6512 - val_mse: 794.6512 - val_mae: 20.8499 - 5s/epoch - 5ms/step

Epoch 19/100

1099/1099 - 5s - loss: 863.2581 - mse: 863.2581 - mae: 22.9083 - val_loss: 808.6322 - val_mse: 808.6322 - val_mae: 21.5732 - 5s/epoch - 5ms/step

Epoch 20/100

1099/1099 - 6s - loss: 860.8761 - mse: 860.8761 - mae: 22.8511 - val_loss: 802.2999 - val_mse: 802.2999 - val_mae: 21.3095 - 6s/epoch - 5ms/step

Epoch 21/100

1099/1099 - 5s - loss: 859.4429 - mse: 859.4429 - mae: 22.8356 - val_loss: 799.8854 - val_mse: 799.8854 - val_mae: 21.2584 - 5s/epoch - 5ms/step

Epoch 22/100

1099/1099 - 5s - loss: 857.9396 - mse: 857.9396 - mae: 22.7988 - val_loss: 793.8793 - val_mse: 793.8793 - val_mae: 20.9540 - 5s/epoch - 5ms/step

Epoch 23/100

1099/1099 - 5s - loss: 857.2796 - mse: 857.2796 - mae: 22.7933 - val_loss: 798.5159 - val_mse: 798.5159 - val_mae: 21.1872 - 5s/epoch - 5ms/step

Epoch 24/100

1099/1099 - 5s - loss: 856.5798 - mse: 856.5798 - mae: 22.7726 - val_loss: 799.2105 - val_mse: 799.2105 - val_mae: 21.2319 - 5s/epoch - 5ms/step

Epoch 25/100

1099/1099 - 5s - loss: 856.6250 - mse: 856.6250 - mae: 22.7826 - val_loss: 789.3838 - val_mse: 789.3838 - val_mae: 20.8428 - 5s/epoch - 5ms/step

Epoch 26/100

1099/1099 - 5s - loss: 856.0882 - mse: 856.0882 - mae: 22.7501 - val_loss: 788.3663 - val_mse: 788.3663 - val_mae: 20.8431 - 5s/epoch - 5ms/step

Epoch 27/100

1099/1099 - 5s - loss: 853.0167 - mse: 853.0167 - mae: 22.7014 - val_loss: 791.9929 - val_mse: 791.9929 - val_mae: 20.8838 - 5s/epoch - 5ms/step

Epoch 28/100

1099/1099 - 5s - loss: 850.5938 - mse: 850.5938 - mae: 22.6742 - val_loss: 793.0940 - val_mse: 793.0940 - val_mae: 21.0624 - 5s/epoch - 5ms/step

Epoch 29/100

1099/1099 - 5s - loss: 852.0378 - mse: 852.0378 - mae: 22.6693 - val_loss: 792.9065 - val_mse: 792.9065 - val_mae: 20.9861 - 5s/epoch - 5ms/step

Epoch 30/100

1099/1099 - 5s - loss: 851.2075 - mse: 851.2075 - mae: 22.6760 - val_loss: 790.7479 - val_mse: 790.7479 - val_mae: 20.9189 - 5s/epoch - 5ms/step

Epoch 31/100

1099/1099 - 5s - loss: 850.1954 - mse: 850.1954 - mae: 22.6553 - val_loss: 794.7260 - val_mse: 794.7260 - val_mae: 21.1272 - 5s/epoch - 5ms/step

Epoch 32/100

1099/1099 - 5s - loss: 847.4686 - mse: 847.4686 - mae: 22.6193 - val_loss: 785.9088 - val_mse: 785.9088 - val_mae: 20.6781 - 5s/epoch - 5ms/step

Epoch 33/100

1099/1099 - 5s - loss: 847.0256 - mse: 847.0256 - mae: 22.5841 - val_loss: 796.6046 - val_mse: 796.6046 - val_mae: 21.2550 - 5s/epoch - 5ms/step

Epoch 34/100

1099/1099 - 5s - loss: 845.9634 - mse: 845.9634 - mae: 22.5704 - val_loss: 788.6296 - val_mse: 788.6296 - val_mae: 20.7392 - 5s/epoch - 5ms/step

Epoch 35/100

1099/1099 - 5s - loss: 846.9263 - mse: 846.9263 - mae: 22.6084 - val_loss: 786.8594 - val_mse: 786.8594 - val_mae: 20.7809 - 5s/epoch - 5ms/step

Epoch 36/100

1099/1099 - 5s - loss: 843.8759 - mse: 843.8759 - mae: 22.5328 - val_loss: 785.4296 - val_mse: 785.4296 - val_mae: 20.7531 - 5s/epoch - 5ms/step

Epoch 37/100

1099/1099 - 5s - loss: 844.3782 - mse: 844.3782 - mae: 22.5569 - val_loss: 786.6532 - val_mse: 786.6532 - val_mae: 20.7867 - 5s/epoch - 5ms/step

Epoch 38/100

1099/1099 - 5s - loss: 842.2573 - mse: 842.2573 - mae: 22.5481 - val_loss: 785.8930 - val_mse: 785.8930 - val_mae: 20.7005 - 5s/epoch - 5ms/step

Epoch 39/100

1099/1099 - 5s - loss: 841.0223 - mse: 841.0223 - mae: 22.5036 - val_loss: 785.2270 - val_mse: 785.2270 - val_mae: 20.7568 - 5s/epoch - 5ms/step

Epoch 40/100

1099/1099 - 5s - loss: 839.7415 - mse: 839.7415 - mae: 22.4802 - val_loss: 780.6349 - val_mse: 780.6349 - val_mae: 20.6000 - 5s/epoch - 5ms/step

Epoch 41/100

1099/1099 - 5s - loss: 837.7990 - mse: 837.7990 - mae: 22.4555 - val_loss: 782.0506 - val_mse: 782.0506 - val_mae: 20.5618 - 5s/epoch - 5ms/step
Epoch 42/100
1099/1099 - 5s - loss: 839.1710 - mse: 839.1710 - mae: 22.4608 - val_loss: 783.9051 - val_mse: 783.9051 - val_mae: 20.7357 - 5s/epoch - 5ms/step
Epoch 43/100
1099/1099 - 5s - loss: 839.1569 - mse: 839.1569 - mae: 22.4801 - val_loss: 785.6073 - val_mse: 785.6073 - val_mae: 20.7970 - 5s/epoch - 5ms/step
Epoch 44/100
1099/1099 - 5s - loss: 837.6735 - mse: 837.6735 - mae: 22.4488 - val_loss: 781.6941 - val_mse: 781.6941 - val_mae: 20.6585 - 5s/epoch - 5ms/step
Epoch 45/100
1099/1099 - 5s - loss: 836.3270 - mse: 836.3270 - mae: 22.4388 - val_loss: 785.6003 - val_mse: 785.6003 - val_mae: 20.8543 - 5s/epoch - 5ms/step
Epoch 46/100
1099/1099 - 5s - loss: 833.8857 - mse: 833.8857 - mae: 22.3855 - val_loss: 783.4772 - val_mse: 783.4772 - val_mae: 20.6841 - 5s/epoch - 5ms/step
Epoch 47/100
1099/1099 - 5s - loss: 833.4081 - mse: 833.4081 - mae: 22.4019 - val_loss: 777.1863 - val_mse: 777.1863 - val_mae: 20.3415 - 5s/epoch - 5ms/step
Epoch 48/100
1099/1099 - 5s - loss: 831.5150 - mse: 831.5150 - mae: 22.3701 - val_loss: 780.5181 - val_mse: 780.5181 - val_mae: 20.5654 - 5s/epoch - 5ms/step
Epoch 49/100
1099/1099 - 5s - loss: 831.5939 - mse: 831.5939 - mae: 22.3649 - val_loss: 780.1572 - val_mse: 780.1572 - val_mae: 20.5903 - 5s/epoch - 5ms/step
Epoch 50/100
1099/1099 - 5s - loss: 831.4705 - mse: 831.4705 - mae: 22.3192 - val_loss: 778.2678 - val_mse: 778.2678 - val_mae: 20.5391 - 5s/epoch - 5ms/step
Epoch 51/100
1099/1099 - 5s - loss: 831.9643 - mse: 831.9643 - mae: 22.3660 - val_loss: 782.8247 - val_mse: 782.8247 - val_mae: 20.8061 - 5s/epoch - 5ms/step
Epoch 52/100
1099/1099 - 5s - loss: 830.5891 - mse: 830.5891 - mae: 22.3440 - val_loss: 780.9832 - val_mse: 780.9832 - val_mae: 20.6971 - 5s/epoch - 5ms/step
Epoch 53/100
1099/1099 - 5s - loss: 828.9745 - mse: 828.9745 - mae: 22.3191 - val_loss: 777.6215 - val_mse: 777.6215 - val_mae: 20.4114 - 5s/epoch - 5ms/step
Epoch 54/100
1099/1099 - 5s - loss: 827.5967 - mse: 827.5967 - mae: 22.2769 - val_loss: 772.5603 - val_mse: 772.5603 - val_mae: 20.2266 - 5s/epoch - 5ms/step
Epoch 55/100
1099/1099 - 5s - loss: 825.4598 - mse: 825.4598 - mae: 22.2607 - val_loss: 770.7588 - val_mse: 770.7588 - val_mae: 20.1677 - 5s/epoch - 5ms/step
Epoch 56/100
1099/1099 - 5s - loss: 826.4714 - mse: 826.4714 - mae: 22.2790 - val_loss: 774.5474 - val_mse: 774.5474 - val_mae: 20.3329 - 5s/epoch - 5ms/step
Epoch 57/100
1099/1099 - 5s - loss: 823.4481 - mse: 823.4481 - mae: 22.2202 - val_loss: 777.5106 - val_mse: 777.5106 - val_mae: 20.5660 - 5s/epoch - 5ms/step
Epoch 58/100
1099/1099 - 5s - loss: 821.6387 - mse: 821.6387 - mae: 22.1786 - val_loss: 779.1291 - val_mse: 779.1291 - val_mae: 20.4938 - 5s/epoch - 5ms/step
Epoch 59/100
1099/1099 - 5s - loss: 823.6133 - mse: 823.6133 - mae: 22.2343 - val_loss: 779.6213 - val_mse: 779.6213 - val_mae: 20.5337 - 5s/epoch - 5ms/step
Epoch 60/100
1099/1099 - 5s - loss: 822.3649 - mse: 822.3649 - mae: 22.1970 - val_loss: 776.4822 - val_mse: 776.4822 - val_mae: 20.5203 - 5s/epoch - 5ms/step
Epoch 61/100
1099/1099 - 5s - loss: 822.7499 - mse: 822.7499 - mae: 22.2089 - val_loss:

773.5281 - val_mse: 773.5281 - val_mae: 20.1520 - 5s/epoch - 5ms/step
Epoch 62/100
1099/1099 - 5s - loss: 820.4150 - mse: 820.4150 - mae: 22.1828 - val_loss:
772.2716 - val_mse: 772.2716 - val_mae: 20.1413 - 5s/epoch - 5ms/step
Epoch 63/100
1099/1099 - 5s - loss: 819.6357 - mse: 819.6357 - mae: 22.1702 - val_loss:
778.8867 - val_mse: 778.8867 - val_mae: 20.6567 - 5s/epoch - 5ms/step
Epoch 64/100
1099/1099 - 5s - loss: 819.9949 - mse: 819.9949 - mae: 22.1569 - val_loss:
774.2969 - val_mse: 774.2969 - val_mae: 20.3342 - 5s/epoch - 5ms/step
Epoch 65/100
1099/1099 - 5s - loss: 815.2855 - mse: 815.2855 - mae: 22.0908 - val_loss:
778.5449 - val_mse: 778.5449 - val_mae: 20.4114 - 5s/epoch - 5ms/step
Epoch 66/100
1099/1099 - 5s - loss: 818.2998 - mse: 818.2998 - mae: 22.1390 - val_loss:
776.1032 - val_mse: 776.1032 - val_mae: 20.1775 - 5s/epoch - 5ms/step
Epoch 67/100
1099/1099 - 5s - loss: 812.8698 - mse: 812.8698 - mae: 22.0474 - val_loss:
776.0057 - val_mse: 776.0057 - val_mae: 20.4508 - 5s/epoch - 5ms/step
Epoch 68/100
1099/1099 - 5s - loss: 815.2606 - mse: 815.2606 - mae: 22.0853 - val_loss:
771.1051 - val_mse: 771.1051 - val_mae: 20.2274 - 5s/epoch - 5ms/step
Epoch 69/100
1099/1099 - 5s - loss: 814.7626 - mse: 814.7626 - mae: 22.0813 - val_loss:
780.0782 - val_mse: 780.0782 - val_mae: 20.4985 - 5s/epoch - 5ms/step
Epoch 70/100
1099/1099 - 5s - loss: 812.7853 - mse: 812.7853 - mae: 22.0271 - val_loss:
774.8277 - val_mse: 774.8277 - val_mae: 20.4737 - 5s/epoch - 5ms/step
Epoch 71/100
1099/1099 - 5s - loss: 813.4115 - mse: 813.4115 - mae: 22.0466 - val_loss:
771.2755 - val_mse: 771.2755 - val_mae: 20.3005 - 5s/epoch - 5ms/step
Epoch 72/100
1099/1099 - 5s - loss: 813.2828 - mse: 813.2828 - mae: 22.0404 - val_loss:
780.2922 - val_mse: 780.2922 - val_mae: 20.6368 - 5s/epoch - 5ms/step
Epoch 73/100
1099/1099 - 5s - loss: 813.0535 - mse: 813.0535 - mae: 22.0122 - val_loss:
776.8722 - val_mse: 776.8722 - val_mae: 20.5459 - 5s/epoch - 5ms/step
Epoch 74/100
1099/1099 - 5s - loss: 809.4827 - mse: 809.4827 - mae: 21.9705 - val_loss:
772.9112 - val_mse: 772.9112 - val_mae: 20.2453 - 5s/epoch - 5ms/step
Epoch 75/100
1099/1099 - 5s - loss: 809.6846 - mse: 809.6846 - mae: 21.9821 - val_loss:
768.9003 - val_mse: 768.9003 - val_mae: 20.0855 - 5s/epoch - 5ms/step
Epoch 76/100
1099/1099 - 5s - loss: 810.8671 - mse: 810.8671 - mae: 22.0016 - val_loss:
775.6877 - val_mse: 775.6877 - val_mae: 20.4716 - 5s/epoch - 5ms/step
Epoch 77/100
1099/1099 - 5s - loss: 808.5057 - mse: 808.5057 - mae: 21.9475 - val_loss:
766.6765 - val_mse: 766.6765 - val_mae: 19.9913 - 5s/epoch - 5ms/step
Epoch 78/100
1099/1099 - 5s - loss: 807.2335 - mse: 807.2335 - mae: 21.9427 - val_loss:
774.2081 - val_mse: 774.2081 - val_mae: 20.5033 - 5s/epoch - 5ms/step
Epoch 79/100
1099/1099 - 5s - loss: 809.0178 - mse: 809.0178 - mae: 21.9694 - val_loss:
770.7395 - val_mse: 770.7395 - val_mae: 20.1981 - 5s/epoch - 5ms/step
Epoch 80/100
1099/1099 - 5s - loss: 807.7751 - mse: 807.7751 - mae: 21.9388 - val_loss:
772.1353 - val_mse: 772.1353 - val_mae: 20.3547 - 5s/epoch - 5ms/step
Epoch 81/100
1099/1099 - 5s - loss: 807.6684 - mse: 807.6684 - mae: 21.9620 - val_loss:
781.0735 - val_mse: 781.0735 - val_mae: 20.7862 - 5s/epoch - 5ms/step

Epoch 82/100

1099/1099 - 5s - loss: 805.5861 - mse: 805.5861 - mae: 21.9140 - val_loss: 768.0352 - val_mse: 768.0352 - val_mae: 20.0247 - 5s/epoch - 5ms/step

Epoch 83/100

1099/1099 - 5s - loss: 806.6795 - mse: 806.6795 - mae: 21.9410 - val_loss: 767.5325 - val_mse: 767.5325 - val_mae: 20.1535 - 5s/epoch - 5ms/step

Epoch 84/100

1099/1099 - 7s - loss: 805.6031 - mse: 805.6031 - mae: 21.9408 - val_loss: 777.2476 - val_mse: 777.2476 - val_mae: 20.5310 - 7s/epoch - 6ms/step

Epoch 85/100

1099/1099 - 5s - loss: 806.6995 - mse: 806.6995 - mae: 21.9089 - val_loss: 766.9566 - val_mse: 766.9566 - val_mae: 20.0425 - 5s/epoch - 5ms/step

Epoch 86/100

1099/1099 - 5s - loss: 803.3943 - mse: 803.3943 - mae: 21.8779 - val_loss: 773.6127 - val_mse: 773.6127 - val_mae: 20.4312 - 5s/epoch - 5ms/step

Epoch 87/100

1099/1099 - 5s - loss: 801.6089 - mse: 801.6089 - mae: 21.8649 - val_loss: 768.2010 - val_mse: 768.2010 - val_mae: 20.0408 - 5s/epoch - 5ms/step

Epoch 88/100

1099/1099 - 5s - loss: 801.9258 - mse: 801.9258 - mae: 21.8406 - val_loss: 770.4070 - val_mse: 770.4070 - val_mae: 20.3055 - 5s/epoch - 5ms/step

Epoch 89/100

1099/1099 - 5s - loss: 803.2374 - mse: 803.2374 - mae: 21.8641 - val_loss: 768.3971 - val_mse: 768.3971 - val_mae: 20.1146 - 5s/epoch - 5ms/step

Epoch 90/100

1099/1099 - 5s - loss: 802.7388 - mse: 802.7388 - mae: 21.8634 - val_loss: 768.3560 - val_mse: 768.3560 - val_mae: 20.0704 - 5s/epoch - 5ms/step

Epoch 91/100

1099/1099 - 5s - loss: 802.4577 - mse: 802.4577 - mae: 21.8509 - val_loss: 775.9255 - val_mse: 775.9255 - val_mae: 20.3974 - 5s/epoch - 5ms/step

Epoch 92/100

1099/1099 - 5s - loss: 800.1537 - mse: 800.1537 - mae: 21.8196 - val_loss: 779.7817 - val_mse: 779.7817 - val_mae: 20.5087 - 5s/epoch - 5ms/step

Epoch 93/100

1099/1099 - 5s - loss: 795.1120 - mse: 795.1120 - mae: 21.7030 - val_loss: 767.5934 - val_mse: 767.5934 - val_mae: 20.0760 - 5s/epoch - 5ms/step

Epoch 94/100

1099/1099 - 5s - loss: 787.8761 - mse: 787.8761 - mae: 21.5206 - val_loss: 765.6669 - val_mse: 765.6669 - val_mae: 19.7639 - 5s/epoch - 5ms/step

Epoch 95/100

1099/1099 - 5s - loss: 786.9590 - mse: 786.9590 - mae: 21.5071 - val_loss: 764.9678 - val_mse: 764.9678 - val_mae: 19.8851 - 5s/epoch - 5ms/step

Epoch 96/100

1099/1099 - 5s - loss: 785.5941 - mse: 785.5941 - mae: 21.4770 - val_loss: 769.7947 - val_mse: 769.7947 - val_mae: 20.1003 - 5s/epoch - 5ms/step

Epoch 97/100

1099/1099 - 5s - loss: 785.4553 - mse: 785.4553 - mae: 21.4629 - val_loss: 763.0295 - val_mse: 763.0295 - val_mae: 19.6182 - 5s/epoch - 5ms/step

Epoch 98/100

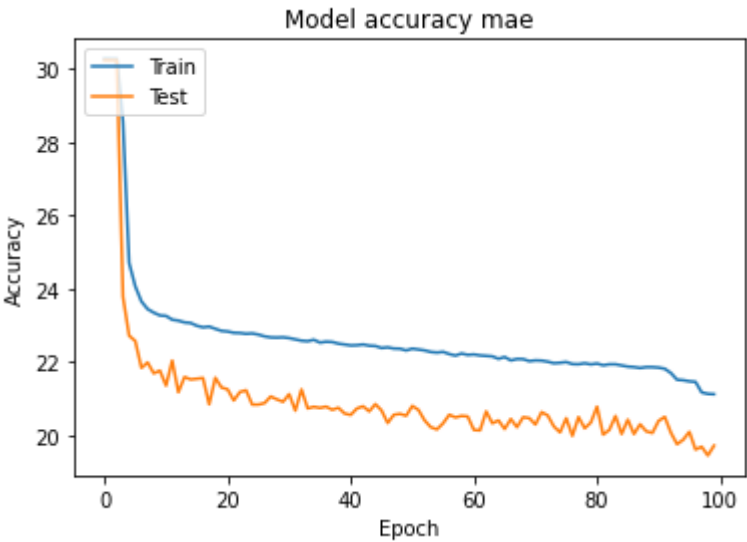
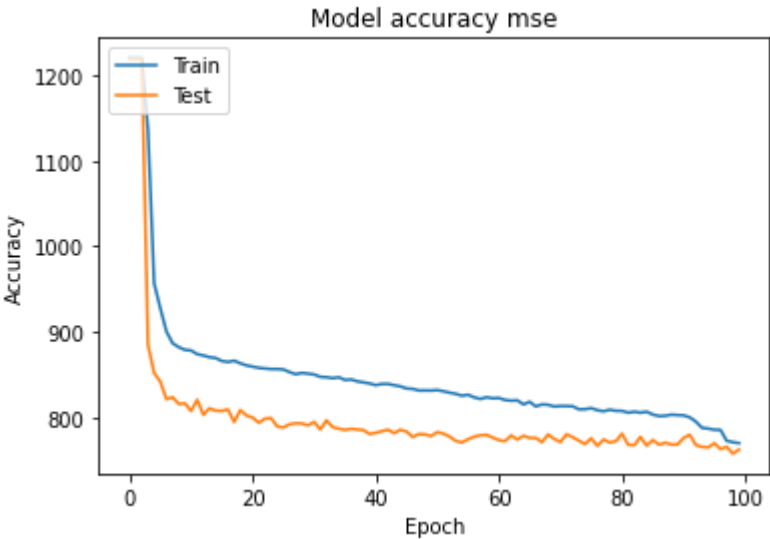
1099/1099 - 5s - loss: 772.7496 - mse: 772.7496 - mae: 21.1741 - val_loss: 765.6617 - val_mse: 765.6617 - val_mae: 19.6940 - 5s/epoch - 5ms/step

Epoch 99/100

1099/1099 - 5s - loss: 771.0470 - mse: 771.0470 - mae: 21.1355 - val_loss: 757.6784 - val_mse: 757.6784 - val_mae: 19.4562 - 5s/epoch - 5ms/step

Epoch 100/100

1099/1099 - 5s - loss: 769.9562 - mse: 769.9562 - mae: 21.1266 - val_loss: 762.3674 - val_mse: 762.3674 - val_mae: 19.7230 - 5s/epoch - 5ms/step



In []:

```
print("Individual magnitude MLP")

layers = (640,200,10)
shape = (640,)
model = create_mlp(shape, layers, True, "relu")
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
    x= x_train_magnitude, y=y_train,
    validation_data=(x_test_magnitude, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual magnitude MLP

Epoch 1/100

1099/1099 - 6s - loss: 1220.7839 - mse: 1220.7839 - mae: 30.2649 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2258 - 6s/epoch - 6ms/step

Epoch 2/100

1099/1099 - 5s - loss: 1220.5559 - mse: 1220.5559 - mae: 30.2629 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2258 - 5s/epoch - 4ms/step

Epoch 3/100

1099/1099 - 5s - loss: 1220.5574 - mse: 1220.5574 - mae: 30.2628 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 4/100

1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 5/100

1099/1099 - 5s - loss: 1220.5537 - mse: 1220.5537 - mae: 30.2628 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 6/100

1099/1099 - 5s - loss: 1220.6068 - mse: 1220.6068 - mae: 30.2638 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 7/100

1099/1099 - 5s - loss: 1220.7002 - mse: 1220.7002 - mae: 30.2641 - val_loss: 1219.2277 - val_mse: 1219.2277 - val_mae: 30.2265 - 5s/epoch - 5ms/step

Epoch 8/100

1099/1099 - 5s - loss: 1220.5594 - mse: 1220.5594 - mae: 30.2630 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 9/100

1099/1099 - 5s - loss: 1220.5563 - mse: 1220.5563 - mae: 30.2629 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 10/100

1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 4ms/step

Epoch 11/100

1099/1099 - 5s - loss: 1220.5571 - mse: 1220.5571 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 12/100

1099/1099 - 5s - loss: 1220.5548 - mse: 1220.5548 - mae: 30.2628 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 13/100

1099/1099 - 5s - loss: 1220.5542 - mse: 1220.5542 - mae: 30.2629 - val_loss: 1219.1741 - val_mse: 1219.1741 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 14/100

1099/1099 - 5s - loss: 1220.5530 - mse: 1220.5530 - mae: 30.2630 - val_loss: 1219.1742 - val_mse: 1219.1742 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 15/100

1099/1099 - 5s - loss: 1220.5533 - mse: 1220.5533 - mae: 30.2629 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 16/100

1099/1099 - 5s - loss: 1220.5538 - mse: 1220.5538 - mae: 30.2629 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 17/100

1099/1099 - 5s - loss: 1220.5543 - mse: 1220.5543 - mae: 30.2629 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 18/100

1099/1099 - 5s - loss: 1220.5555 - mse: 1220.5555 - mae: 30.2629 - val_loss: 1219.1753 - val_mse: 1219.1753 - val_mae: 30.2259 - 5s/epoch - 4ms/step

Epoch 19/100

1099/1099 - 5s - loss: 1220.6040 - mse: 1220.6040 - mae: 30.2631 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 20/100

1099/1099 - 5s - loss: 1220.5562 - mse: 1220.5562 - mae: 30.2629 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 21/100

1099/1099 - 5s - loss: 1220.5554 - mse: 1220.5554 - mae: 30.2629 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 22/100

1099/1099 - 5s - loss: 1220.5546 - mse: 1220.5546 - mae: 30.2629 - val_loss: 1219.1743 - val_mse: 1219.1743 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 23/100

1099/1099 - 5s - loss: 1220.5546 - mse: 1220.5546 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 24/100

1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 25/100

1099/1099 - 5s - loss: 1220.5554 - mse: 1220.5554 - mae: 30.2628 - val_loss: 1219.1742 - val_mse: 1219.1742 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 26/100

1099/1099 - 5s - loss: 1220.6368 - mse: 1220.6368 - mae: 30.2628 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 27/100

1099/1099 - 5s - loss: 1220.5586 - mse: 1220.5586 - mae: 30.2630 - val_loss: 1219.3418 - val_mse: 1219.3418 - val_mae: 30.2274 - 5s/epoch - 5ms/step

Epoch 28/100

1099/1099 - 5s - loss: 1220.5573 - mse: 1220.5573 - mae: 30.2626 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2259 - 5s/epoch - 4ms/step

Epoch 29/100

1099/1099 - 5s - loss: 1220.5592 - mse: 1220.5592 - mae: 30.2629 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 30/100

1099/1099 - 5s - loss: 1220.5536 - mse: 1220.5536 - mae: 30.2628 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 31/100

1099/1099 - 6s - loss: 1220.5540 - mse: 1220.5540 - mae: 30.2628 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 6s/epoch - 6ms/step

Epoch 32/100

1099/1099 - 5s - loss: 1220.5548 - mse: 1220.5548 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 33/100

1099/1099 - 5s - loss: 1220.5562 - mse: 1220.5562 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2258 - 5s/epoch - 4ms/step

Epoch 34/100

1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 4ms/step

Epoch 35/100

1099/1099 - 5s - loss: 1220.5543 - mse: 1220.5543 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 36/100

1099/1099 - 5s - loss: 1220.5548 - mse: 1220.5548 - mae: 30.2628 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 37/100

1099/1099 - 5s - loss: 1220.5558 - mse: 1220.5558 - mae: 30.2628 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 38/100

1099/1099 - 5s - loss: 1220.5536 - mse: 1220.5536 - mae: 30.2628 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 39/100

1099/1099 - 5s - loss: 1220.6136 - mse: 1220.6136 - mae: 30.2636 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 40/100

1099/1099 - 5s - loss: 1220.5538 - mse: 1220.5538 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 41/100

1099/1099 - 5s - loss: 1220.6646 - mse: 1220.6646 - mae: 30.2636 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 42/100
1099/1099 - 5s - loss: 1220.5562 - mse: 1220.5562 - mae: 30.2628 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 43/100
1099/1099 - 5s - loss: 1220.5581 - mse: 1220.5581 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 44/100
1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 45/100
1099/1099 - 5s - loss: 1220.5524 - mse: 1220.5524 - mae: 30.2628 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 46/100
1099/1099 - 5s - loss: 1220.5624 - mse: 1220.5624 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 47/100
1099/1099 - 5s - loss: 1220.5538 - mse: 1220.5538 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 48/100
1099/1099 - 5s - loss: 1220.5552 - mse: 1220.5552 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 49/100
1099/1099 - 5s - loss: 1220.5543 - mse: 1220.5543 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 50/100
1099/1099 - 5s - loss: 1220.5549 - mse: 1220.5549 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 51/100
1099/1099 - 5s - loss: 1220.5549 - mse: 1220.5549 - mae: 30.2629 - val_loss: 1219.1742 - val_mse: 1219.1742 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 52/100
1099/1099 - 5s - loss: 1220.5854 - mse: 1220.5854 - mae: 30.2628 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 53/100
1099/1099 - 5s - loss: 1220.5199 - mse: 1220.5199 - mae: 30.2622 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 54/100
1099/1099 - 5s - loss: 1220.5732 - mse: 1220.5732 - mae: 30.2629 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 55/100
1099/1099 - 5s - loss: 1220.5548 - mse: 1220.5548 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 56/100
1099/1099 - 5s - loss: 1220.5541 - mse: 1220.5541 - mae: 30.2628 - val_loss: 1219.1753 - val_mse: 1219.1753 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 57/100
1099/1099 - 5s - loss: 1220.5817 - mse: 1220.5817 - mae: 30.2631 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 58/100
1099/1099 - 5s - loss: 1220.5624 - mse: 1220.5624 - mae: 30.2628 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 59/100
1099/1099 - 5s - loss: 1220.5621 - mse: 1220.5621 - mae: 30.2630 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 60/100
1099/1099 - 5s - loss: 1220.5540 - mse: 1220.5540 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 61/100
1099/1099 - 5s - loss: 1220.5730 - mse: 1220.5730 - mae: 30.2629 - val_loss:

s: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 62/100
1099/1099 - 5s - loss: 1220.5731 - mse: 1220.5731 - mae: 30.2631 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 63/100
1099/1099 - 5s - loss: 1220.5590 - mse: 1220.5590 - mae: 30.2629 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 64/100
1099/1099 - 5s - loss: 1220.5580 - mse: 1220.5580 - mae: 30.2628 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 65/100
1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 66/100
1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 67/100
1099/1099 - 5s - loss: 1220.5575 - mse: 1220.5575 - mae: 30.2629 - val_loss: 1219.1743 - val_mse: 1219.1743 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 68/100
1099/1099 - 5s - loss: 1220.5543 - mse: 1220.5543 - mae: 30.2629 - val_loss: 1219.1743 - val_mse: 1219.1743 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 69/100
1099/1099 - 5s - loss: 1220.5541 - mse: 1220.5541 - mae: 30.2629 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 70/100
1099/1099 - 5s - loss: 1220.5530 - mse: 1220.5530 - mae: 30.2628 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 71/100
1099/1099 - 5s - loss: 1220.5547 - mse: 1220.5547 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 72/100
1099/1099 - 5s - loss: 1220.5537 - mse: 1220.5537 - mae: 30.2628 - val_loss: 1219.1757 - val_mse: 1219.1757 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 73/100
1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 74/100
1099/1099 - 5s - loss: 1220.5547 - mse: 1220.5547 - mae: 30.2628 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 75/100
1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 76/100
1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2628 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 77/100
1099/1099 - 5s - loss: 1220.5546 - mse: 1220.5546 - mae: 30.2628 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 5s/epoch - 5ms/step
Epoch 78/100
1099/1099 - 6s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2259 - 6s/epoch - 5ms/step
Epoch 79/100
1099/1099 - 5s - loss: 1220.5541 - mse: 1220.5541 - mae: 30.2629 - val_loss: 1219.1740 - val_mse: 1219.1740 - val_mae: 30.2258 - 5s/epoch - 5ms/step
Epoch 80/100
1099/1099 - 5s - loss: 1220.5541 - mse: 1220.5541 - mae: 30.2628 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 4ms/step
Epoch 81/100
1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2629 - val_loss: 1219.1743 - val_mse: 1219.1743 - val_mae: 30.2258 - 5s/epoch - 4ms/step

Epoch 82/100

1099/1099 - 5s - loss: 1220.5543 - mse: 1220.5543 - mae: 30.2628 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 83/100

1099/1099 - 5s - loss: 1220.5552 - mse: 1220.5552 - mae: 30.2628 - val_loss: 1219.1735 - val_mse: 1219.1735 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 84/100

1099/1099 - 5s - loss: 1220.5538 - mse: 1220.5538 - mae: 30.2628 - val_loss: 1219.1740 - val_mse: 1219.1740 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 85/100

1099/1099 - 5s - loss: 1220.5541 - mse: 1220.5541 - mae: 30.2628 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 86/100

1099/1099 - 5s - loss: 1220.5551 - mse: 1220.5551 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 87/100

1099/1099 - 5s - loss: 1220.5546 - mse: 1220.5546 - mae: 30.2629 - val_loss: 1219.1749 - val_mse: 1219.1749 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 88/100

1099/1099 - 5s - loss: 1220.5542 - mse: 1220.5542 - mae: 30.2630 - val_loss: 1219.1754 - val_mse: 1219.1754 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 89/100

1099/1099 - 5s - loss: 1220.5553 - mse: 1220.5553 - mae: 30.2629 - val_loss: 1219.1758 - val_mse: 1219.1758 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 90/100

1099/1099 - 5s - loss: 1220.5552 - mse: 1220.5552 - mae: 30.2629 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 91/100

1099/1099 - 5s - loss: 1220.5531 - mse: 1220.5531 - mae: 30.2629 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 92/100

1099/1099 - 5s - loss: 1220.5536 - mse: 1220.5536 - mae: 30.2628 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 93/100

1099/1099 - 5s - loss: 1220.5541 - mse: 1220.5541 - mae: 30.2629 - val_loss: 1219.1748 - val_mse: 1219.1748 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 94/100

1099/1099 - 5s - loss: 1220.5544 - mse: 1220.5544 - mae: 30.2628 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 95/100

1099/1099 - 5s - loss: 1220.5538 - mse: 1220.5538 - mae: 30.2628 - val_loss: 1219.1750 - val_mse: 1219.1750 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 96/100

1099/1099 - 5s - loss: 1220.5536 - mse: 1220.5536 - mae: 30.2629 - val_loss: 1219.1744 - val_mse: 1219.1744 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 97/100

1099/1099 - 5s - loss: 1220.5542 - mse: 1220.5542 - mae: 30.2628 - val_loss: 1219.1752 - val_mse: 1219.1752 - val_mae: 30.2259 - 5s/epoch - 5ms/step

Epoch 98/100

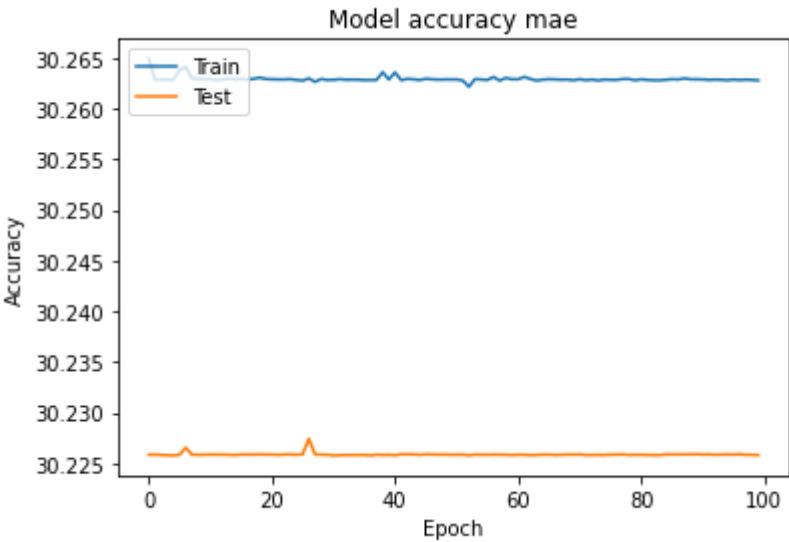
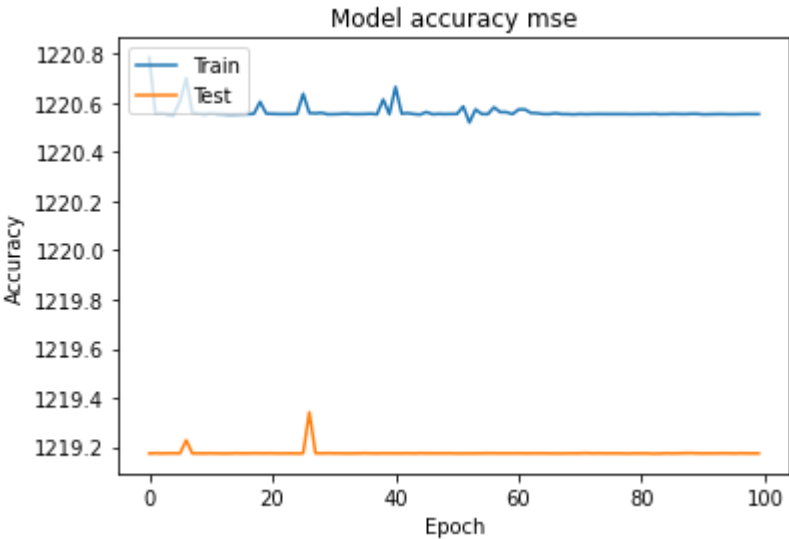
1099/1099 - 5s - loss: 1220.5546 - mse: 1220.5546 - mae: 30.2629 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 99/100

1099/1099 - 5s - loss: 1220.5543 - mse: 1220.5543 - mae: 30.2628 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 5s/epoch - 5ms/step

Epoch 100/100

1099/1099 - 5s - loss: 1220.5543 - mse: 1220.5543 - mae: 30.2628 - val_loss: 1219.1747 - val_mse: 1219.1747 - val_mae: 30.2258 - 5s/epoch - 5ms/step



In []:

```
print("Individual phase 1D CNN")

shape=(640,1)
filters=(64,64)
layers=(100,)
epochs = 25
model = create_1d_cnn(shape, True, filters, layers, 'relu')
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse','mae'])

history = model.fit(
    x= x_train_phase, y=y_train,
    validation_data=(x_test_phase, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual phase 1D CNN

Epoch 1/25

1099/1099 - 62s - loss: 1094.3363 - mse: 1094.3363 - mae: 27.8587 - val_loss: 953.8652 - val_mse: 953.8652 - val_mae: 25.3143 - 62s/epoch - 57ms/step

Epoch 2/25

1099/1099 - 63s - loss: 977.5836 - mse: 977.5836 - mae: 25.4655 - val_loss: 910.1144 - val_mse: 910.1144 - val_mae: 24.3772 - 63s/epoch - 58ms/step

Epoch 3/25

1099/1099 - 61s - loss: 944.4485 - mse: 944.4485 - mae: 24.7937 - val_loss: 881.5477 - val_mse: 881.5477 - val_mae: 23.6934 - 61s/epoch - 56ms/step

Epoch 4/25

1099/1099 - 61s - loss: 920.5392 - mse: 920.5392 - mae: 24.3208 - val_loss: 866.0609 - val_mse: 866.0609 - val_mae: 23.3612 - 61s/epoch - 56ms/step

Epoch 5/25

1099/1099 - 61s - loss: 896.2507 - mse: 896.2507 - mae: 23.8269 - val_loss: 845.9401 - val_mse: 845.9401 - val_mae: 22.8426 - 61s/epoch - 56ms/step

Epoch 6/25

1099/1099 - 61s - loss: 875.0377 - mse: 875.0377 - mae: 23.4032 - val_loss: 831.4785 - val_mse: 831.4785 - val_mae: 22.4510 - 61s/epoch - 55ms/step

Epoch 7/25

1099/1099 - 61s - loss: 857.3379 - mse: 857.3379 - mae: 23.0070 - val_loss: 820.8966 - val_mse: 820.8966 - val_mae: 22.1749 - 61s/epoch - 55ms/step

Epoch 8/25

1099/1099 - 61s - loss: 843.3318 - mse: 843.3318 - mae: 22.7562 - val_loss: 815.7764 - val_mse: 815.7764 - val_mae: 22.0982 - 61s/epoch - 55ms/step

Epoch 9/25

1099/1099 - 61s - loss: 831.2468 - mse: 831.2468 - mae: 22.4830 - val_loss: 816.5062 - val_mse: 816.5062 - val_mae: 22.1888 - 61s/epoch - 55ms/step

Epoch 10/25

1099/1099 - 61s - loss: 820.9103 - mse: 820.9103 - mae: 22.2593 - val_loss: 805.7620 - val_mse: 805.7620 - val_mae: 21.8988 - 61s/epoch - 56ms/step

Epoch 11/25

1099/1099 - 62s - loss: 809.6747 - mse: 809.6747 - mae: 22.0308 - val_loss: 791.4181 - val_mse: 791.4181 - val_mae: 21.4698 - 62s/epoch - 56ms/step

Epoch 12/25

1099/1099 - 61s - loss: 799.5540 - mse: 799.5540 - mae: 21.8225 - val_loss: 792.6760 - val_mse: 792.6760 - val_mae: 21.5731 - 61s/epoch - 55ms/step

Epoch 13/25

1099/1099 - 61s - loss: 788.3620 - mse: 788.3620 - mae: 21.6014 - val_loss: 785.6972 - val_mse: 785.6972 - val_mae: 21.4093 - 61s/epoch - 56ms/step

Epoch 14/25

1099/1099 - 62s - loss: 778.9143 - mse: 778.9143 - mae: 21.4156 - val_loss: 777.0561 - val_mse: 777.0561 - val_mae: 21.2021 - 62s/epoch - 56ms/step

Epoch 15/25

1099/1099 - 61s - loss: 771.2545 - mse: 771.2545 - mae: 21.2507 - val_loss: 775.2806 - val_mse: 775.2806 - val_mae: 21.1439 - 61s/epoch - 56ms/step

Epoch 16/25

1099/1099 - 61s - loss: 763.8821 - mse: 763.8821 - mae: 21.0912 - val_loss: 774.5029 - val_mse: 774.5029 - val_mae: 21.1852 - 61s/epoch - 56ms/step

Epoch 17/25

1099/1099 - 62s - loss: 758.8307 - mse: 758.8307 - mae: 21.0102 - val_loss: 771.9975 - val_mse: 771.9975 - val_mae: 21.0836 - 62s/epoch - 56ms/step

Epoch 18/25

1099/1099 - 61s - loss: 751.6132 - mse: 751.6132 - mae: 20.8750 - val_loss: 768.0151 - val_mse: 768.0151 - val_mae: 20.9263 - 61s/epoch - 55ms/step

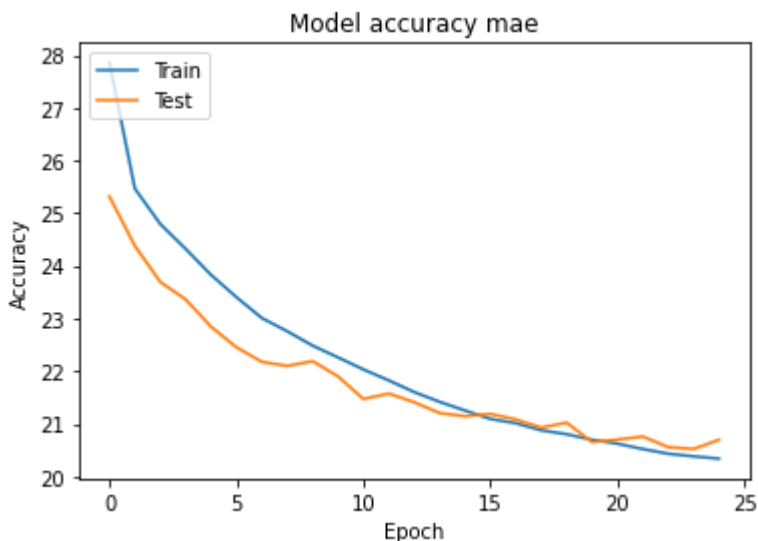
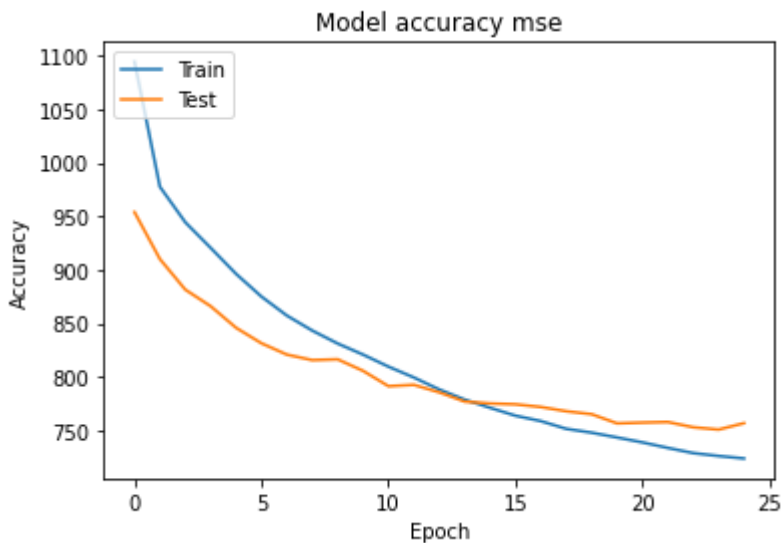
Epoch 19/25

1099/1099 - 61s - loss: 748.0280 - mse: 748.0280 - mae: 20.8018 - val_loss: 765.2794 - val_mse: 765.2794 - val_mae: 21.0206 - 61s/epoch - 56ms/step

Epoch 20/25

1099/1099 - 61s - loss: 743.5424 - mse: 743.5424 - mae: 20.6953 - val_loss:

s: 756.7167 - val_mse: 756.7167 - val_mae: 20.6528 - 61s/epoch - 56ms/step
Epoch 21/25
1099/1099 - 62s - loss: 738.9544 - mse: 738.9544 - mae: 20.6218 - val_loss:
s: 757.4184 - val_mse: 757.4184 - val_mae: 20.6981 - 62s/epoch - 56ms/step
Epoch 22/25
1099/1099 - 61s - loss: 733.7881 - mse: 733.7881 - mae: 20.5195 - val_loss:
s: 757.9689 - val_mse: 757.9689 - val_mae: 20.7576 - 61s/epoch - 55ms/step
Epoch 23/25
1099/1099 - 61s - loss: 728.9540 - mse: 728.9540 - mae: 20.4306 - val_loss:
s: 753.0603 - val_mse: 753.0603 - val_mae: 20.5563 - 61s/epoch - 56ms/step
Epoch 24/25
1099/1099 - 61s - loss: 726.2410 - mse: 726.2410 - mae: 20.3808 - val_loss:
s: 750.9150 - val_mse: 750.9150 - val_mae: 20.5215 - 61s/epoch - 56ms/step
Epoch 25/25
1099/1099 - 62s - loss: 723.9215 - mse: 723.9215 - mae: 20.3374 - val_loss:
s: 756.8724 - val_mse: 756.8724 - val_mae: 20.6954 - 62s/epoch - 56ms/step



In []:

```
print("Individual magnitude 1D CNN")

shape=(640,1)
filters=(64,64)
layers=(100,)
epochs = 25
model = create_1d_cnn(shape, True, filters, layers, 'relu')
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse','mae'])

history = model.fit(
    x= x_train_magnitude, y=y_train,
    validation_data=(x_test_magnitude, y_test),
    epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)
```

Individual magnitude 1D CNN

Epoch 1/25

1099/1099 - 73s - loss: 1216.3594 - mse: 1216.3594 - mae: 30.1913 - val_loss: 1182.2737 - val_mse: 1182.2737 - val_mae: 29.6565 - 73s/epoch - 67ms/step

Epoch 2/25

1099/1099 - 72s - loss: 1132.5471 - mse: 1132.5471 - mae: 28.5943 - val_loss: 1091.3628 - val_mse: 1091.3628 - val_mae: 27.9647 - 72s/epoch - 66ms/step

Epoch 3/25

1099/1099 - 76s - loss: 1098.9058 - mse: 1098.9058 - mae: 27.9285 - val_loss: 1067.0024 - val_mse: 1067.0024 - val_mae: 27.5255 - 76s/epoch - 69ms/step

Epoch 4/25

1099/1099 - 72s - loss: 1073.8809 - mse: 1073.8809 - mae: 27.4522 - val_loss: 1033.5162 - val_mse: 1033.5162 - val_mae: 26.8991 - 72s/epoch - 65ms/step

Epoch 5/25

1099/1099 - 72s - loss: 1040.9642 - mse: 1040.9642 - mae: 26.8747 - val_loss: 994.1068 - val_mse: 994.1068 - val_mae: 26.1461 - 72s/epoch - 65ms/step

Epoch 6/25

1099/1099 - 72s - loss: 1004.5599 - mse: 1004.5599 - mae: 26.2014 - val_loss: 962.6041 - val_mse: 962.6041 - val_mae: 25.4996 - 72s/epoch - 65ms/step

Epoch 7/25

1099/1099 - 72s - loss: 971.5823 - mse: 971.5823 - mae: 25.5969 - val_loss: 936.8146 - val_mse: 936.8146 - val_mae: 24.9493 - 72s/epoch - 65ms/step

Epoch 8/25

1099/1099 - 72s - loss: 945.7045 - mse: 945.7045 - mae: 25.0946 - val_loss: 914.2786 - val_mse: 914.2786 - val_mae: 24.5457 - 72s/epoch - 65ms/step

Epoch 9/25

1099/1099 - 72s - loss: 928.9356 - mse: 928.9356 - mae: 24.7984 - val_loss: 901.9387 - val_mse: 901.9387 - val_mae: 24.2809 - 72s/epoch - 65ms/step

Epoch 10/25

1099/1099 - 72s - loss: 916.1290 - mse: 916.1290 - mae: 24.5222 - val_loss: 892.2993 - val_mse: 892.2993 - val_mae: 24.0767 - 72s/epoch - 66ms/step

Epoch 11/25

1099/1099 - 72s - loss: 902.1500 - mse: 902.1500 - mae: 24.2527 - val_loss: 877.1819 - val_mse: 877.1819 - val_mae: 23.6457 - 72s/epoch - 66ms/step

Epoch 12/25

1099/1099 - 72s - loss: 892.8614 - mse: 892.8614 - mae: 24.0539 - val_loss: 877.1057 - val_mse: 877.1057 - val_mae: 23.7345 - 72s/epoch - 66ms/step

Epoch 13/25

1099/1099 - 73s - loss: 883.9883 - mse: 883.9883 - mae: 23.8821 - val_loss: 858.3151 - val_mse: 858.3151 - val_mae: 23.1963 - 73s/epoch - 66ms/step

Epoch 14/25

1099/1099 - 73s - loss: 875.7617 - mse: 875.7617 - mae: 23.7119 - val_loss: 861.3057 - val_mse: 861.3057 - val_mae: 23.3030 - 73s/epoch - 66ms/step

Epoch 15/25

1099/1099 - 73s - loss: 866.4295 - mse: 866.4295 - mae: 23.5391 - val_loss: 862.5668 - val_mse: 862.5668 - val_mae: 23.3148 - 73s/epoch - 66ms/step

Epoch 16/25

1099/1099 - 75s - loss: 861.5657 - mse: 861.5657 - mae: 23.4244 - val_loss: 842.3000 - val_mse: 842.3000 - val_mae: 22.7685 - 75s/epoch - 68ms/step

Epoch 17/25

1099/1099 - 72s - loss: 854.7042 - mse: 854.7042 - mae: 23.2806 - val_loss: 849.0013 - val_mse: 849.0013 - val_mae: 22.9331 - 72s/epoch - 66ms/step

Epoch 18/25

1099/1099 - 72s - loss: 852.2365 - mse: 852.2365 - mae: 23.2080 - val_loss: 840.9349 - val_mse: 840.9349 - val_mae: 22.7363 - 72s/epoch - 66ms/step

Epoch 19/25

1099/1099 - 73s - loss: 845.7142 - mse: 845.7142 - mae: 23.0816 - val_loss: 834.5481 - val_mse: 834.5481 - val_mae: 22.6427 - 73s/epoch - 66ms/step

Epoch 20/25

1099/1099 - 73s - loss: 841.6362 - mse: 841.6362 - mae: 22.9734 - val_loss: 833.2715 - val_mse: 833.2715 - val_mae: 22.5754 - 73s/epoch - 66ms/step

Epoch 21/25

1099/1099 - 73s - loss: 834.4493 - mse: 834.4493 - mae: 22.8413 - val_loss: 832.7162 - val_mse: 832.7162 - val_mae: 22.5642 - 73s/epoch - 66ms/step

Epoch 22/25

1099/1099 - 73s - loss: 832.5697 - mse: 832.5697 - mae: 22.7994 - val_loss: 830.4850 - val_mse: 830.4850 - val_mae: 22.4547 - 73s/epoch - 66ms/step

Epoch 23/25

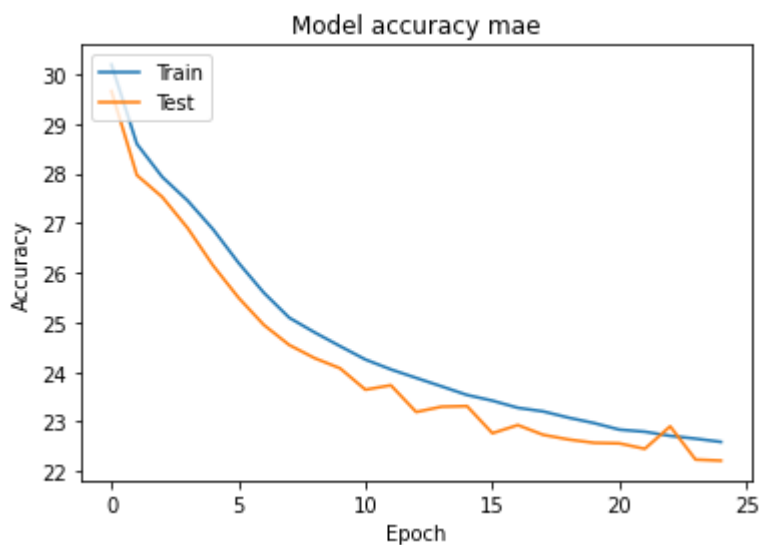
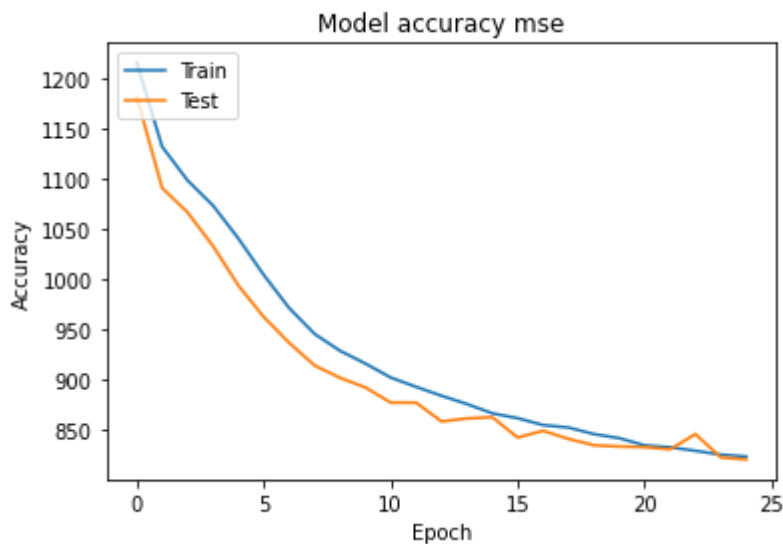
1099/1099 - 72s - loss: 829.0084 - mse: 829.0084 - mae: 22.7159 - val_loss: 845.7101 - val_mse: 845.7101 - val_mae: 22.9071 - 72s/epoch - 66ms/step

Epoch 24/25

1099/1099 - 72s - loss: 825.1785 - mse: 825.1785 - mae: 22.6592 - val_loss: 822.3644 - val_mse: 822.3644 - val_mae: 22.2378 - 72s/epoch - 66ms/step

Epoch 25/25

1099/1099 - 72s - loss: 823.2281 - mse: 823.2281 - mae: 22.5941 - val_loss: 820.3568 - val_mse: 820.3568 - val_mae: 22.2167 - 72s/epoch - 65ms/step



Best Models Improvements

For the best models achieved against the data where the results are yet to plateau the epochs have been increased

In []:

```
antenna_num = 8

magnitude = pd.read_csv('/content/drive/MyDrive/train_magnitude_8.csv', header=None).to_numpy()
output_data = pd.read_csv('/content/drive/MyDrive/train_outputs_8.csv', header=None).to_numpy()
phase = pd.read_csv('/content/drive/MyDrive/train_phase_8.csv', header=None).to_numpy()

data = load_data(phase, magnitude, output_data, antenna_num)

phase_data = data[0]
magnitude_data = data[1]
output_data = data[2]

reduced_data = perform_dimensionality_reduction(phase_data, magnitude_data)
phase_data = reduced_data[0]
magnitude_data = reduced_data[1]

data_split = split_test_train(phase_data, magnitude_data, output_data, 0.4)
x_train_magnitude = data_split[0]
x_test_magnitude = data_split[1]
x_train_phase = data_split[2]
x_test_phase = data_split[3]
y_train = data_split[4][:,0:2]
y_test = data_split[5][:,0:2]

lr = 0.001
epochs = 100
opt = Adam(learning_rate=lr)
```

In []:

```
print("Combined phase and magnitude MLP")

layers = (640,200,10)
shape = (640,)
epochs = 300
magnitude = create_mlp(shape, layers, False, "relu")
phase = create_mlp(shape, layers, False, "relu")

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
x=[x_train_magnitude, x_train_phase], y=y_train,
  validation_data=([x_test_magnitude, x_test_phase], y_test),
  epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)

comparison = MUSIC_metrics(data_split[5])
print("MUSIC MSE: ", comparison[1])
print("MUSIC MAE: ", comparison[0])
print("Out of range MUSIC prediction: ", len(comparison[2]))
```

Combined phase and magnitude MLP

Epoch 1/300

1099/1099 - 10s - loss: 1022.4969 - mse: 1022.4969 - mae: 26.2443 - val_loss: 855.4550 - val_mse: 855.4550 - val_mae: 22.8329 - 10s/epoch - 9ms/step

Epoch 2/300

1099/1099 - 8s - loss: 861.1420 - mse: 861.1420 - mae: 22.7194 - val_loss: 843.6713 - val_mse: 843.6713 - val_mae: 22.6047 - 8s/epoch - 8ms/step

Epoch 3/300

1099/1099 - 9s - loss: 838.6165 - mse: 838.6165 - mae: 22.1139 - val_loss: 830.5241 - val_mse: 830.5241 - val_mae: 22.2222 - 9s/epoch - 8ms/step

Epoch 4/300

1099/1099 - 9s - loss: 827.7082 - mse: 827.7082 - mae: 21.8149 - val_loss: 832.0359 - val_mse: 832.0359 - val_mae: 22.3530 - 9s/epoch - 8ms/step

Epoch 5/300

1099/1099 - 9s - loss: 819.2601 - mse: 819.2601 - mae: 21.6034 - val_loss: 828.3931 - val_mse: 828.3931 - val_mae: 22.2326 - 9s/epoch - 8ms/step

Epoch 6/300

1099/1099 - 9s - loss: 814.8217 - mse: 814.8217 - mae: 21.4598 - val_loss: 829.8304 - val_mse: 829.8304 - val_mae: 22.2895 - 9s/epoch - 8ms/step

Epoch 7/300

1099/1099 - 8s - loss: 812.1302 - mse: 812.1302 - mae: 21.3527 - val_loss: 839.7855 - val_mse: 839.7855 - val_mae: 22.6437 - 8s/epoch - 8ms/step

Epoch 8/300

1099/1099 - 8s - loss: 807.1083 - mse: 807.1083 - mae: 21.2490 - val_loss: 819.0689 - val_mse: 819.0689 - val_mae: 21.8788 - 8s/epoch - 8ms/step

Epoch 9/300

1099/1099 - 8s - loss: 803.5217 - mse: 803.5217 - mae: 21.1432 - val_loss: 828.4592 - val_mse: 828.4592 - val_mae: 22.3367 - 8s/epoch - 8ms/step

Epoch 10/300

1099/1099 - 8s - loss: 801.1003 - mse: 801.1003 - mae: 21.0428 - val_loss: 829.8442 - val_mse: 829.8442 - val_mae: 22.3395 - 8s/epoch - 8ms/step

Epoch 11/300

1099/1099 - 9s - loss: 798.5827 - mse: 798.5827 - mae: 20.9712 - val_loss: 807.3620 - val_mse: 807.3620 - val_mae: 21.4556 - 9s/epoch - 8ms/step

Epoch 12/300

1099/1099 - 9s - loss: 796.5624 - mse: 796.5624 - mae: 20.9092 - val_loss: 820.9234 - val_mse: 820.9234 - val_mae: 22.0964 - 9s/epoch - 8ms/step

Epoch 13/300

1099/1099 - 8s - loss: 792.7118 - mse: 792.7118 - mae: 20.8041 - val_loss: 810.0483 - val_mse: 810.0483 - val_mae: 21.6354 - 8s/epoch - 8ms/step

Epoch 14/300

1099/1099 - 9s - loss: 789.6367 - mse: 789.6367 - mae: 20.7162 - val_loss: 818.6429 - val_mse: 818.6429 - val_mae: 21.9817 - 9s/epoch - 8ms/step

Epoch 15/300

1099/1099 - 9s - loss: 786.9794 - mse: 786.9794 - mae: 20.6370 - val_loss: 807.8371 - val_mse: 807.8371 - val_mae: 21.5714 - 9s/epoch - 8ms/step

Epoch 16/300

1099/1099 - 9s - loss: 785.4833 - mse: 785.4833 - mae: 20.6018 - val_loss: 822.9161 - val_mse: 822.9161 - val_mae: 22.2339 - 9s/epoch - 8ms/step

Epoch 17/300

1099/1099 - 9s - loss: 782.0079 - mse: 782.0079 - mae: 20.5093 - val_loss: 813.4305 - val_mse: 813.4305 - val_mae: 21.8674 - 9s/epoch - 8ms/step

Epoch 18/300

1099/1099 - 9s - loss: 781.7501 - mse: 781.7501 - mae: 20.5025 - val_loss: 809.2002 - val_mse: 809.2002 - val_mae: 21.7064 - 9s/epoch - 8ms/step

Epoch 19/300

1099/1099 - 8s - loss: 778.7294 - mse: 778.7294 - mae: 20.4338 - val_loss: 812.2675 - val_mse: 812.2675 - val_mae: 21.8530 - 8s/epoch - 8ms/step

Epoch 20/300

1099/1099 - 8s - loss: 777.5843 - mse: 777.5843 - mae: 20.4091 - val_loss: 802.4937 - val_mse: 802.4937 - val_mae: 21.4123 - 8s/epoch - 8ms/step

Epoch 21/300

1099/1099 - 9s - loss: 774.9998 - mse: 774.9998 - mae: 20.3810 - val_loss: 807.8304 - val_mse: 807.8304 - val_mae: 21.6603 - 9s/epoch - 8ms/step

Epoch 22/300

1099/1099 - 8s - loss: 773.1270 - mse: 773.1270 - mae: 20.3192 - val_loss: 793.3500 - val_mse: 793.3500 - val_mae: 21.0247 - 8s/epoch - 8ms/step

Epoch 23/300

1099/1099 - 8s - loss: 769.9786 - mse: 769.9786 - mae: 20.2573 - val_loss: 810.0205 - val_mse: 810.0205 - val_mae: 21.7535 - 8s/epoch - 8ms/step

Epoch 24/300

1099/1099 - 8s - loss: 766.6345 - mse: 766.6345 - mae: 20.2029 - val_loss: 801.3423 - val_mse: 801.3423 - val_mae: 21.4776 - 8s/epoch - 8ms/step

Epoch 25/300

1099/1099 - 9s - loss: 762.8917 - mse: 762.8917 - mae: 20.1326 - val_loss: 801.3749 - val_mse: 801.3749 - val_mae: 21.5610 - 9s/epoch - 8ms/step

Epoch 26/300

1099/1099 - 10s - loss: 759.0744 - mse: 759.0744 - mae: 20.0390 - val_loss: 793.0901 - val_mse: 793.0901 - val_mae: 21.2364 - 10s/epoch - 9ms/step

Epoch 27/300

1099/1099 - 9s - loss: 751.9490 - mse: 751.9490 - mae: 19.8781 - val_loss: 790.5316 - val_mse: 790.5316 - val_mae: 21.2160 - 9s/epoch - 8ms/step

Epoch 28/300

1099/1099 - 9s - loss: 744.6488 - mse: 744.6488 - mae: 19.7601 - val_loss: 786.9468 - val_mse: 786.9468 - val_mae: 21.0985 - 9s/epoch - 8ms/step

Epoch 29/300

1099/1099 - 9s - loss: 739.7034 - mse: 739.7034 - mae: 19.6401 - val_loss: 786.3522 - val_mse: 786.3522 - val_mae: 21.3125 - 9s/epoch - 8ms/step

Epoch 30/300

1099/1099 - 8s - loss: 730.3490 - mse: 730.3490 - mae: 19.4446 - val_loss: 779.2560 - val_mse: 779.2560 - val_mae: 21.0367 - 8s/epoch - 8ms/step

Epoch 31/300

1099/1099 - 9s - loss: 721.9631 - mse: 721.9631 - mae: 19.2894 - val_loss: 770.7354 - val_mse: 770.7354 - val_mae: 20.8339 - 9s/epoch - 8ms/step

Epoch 32/300

1099/1099 - 9s - loss: 712.4026 - mse: 712.4026 - mae: 19.0982 - val_loss: 759.6879 - val_mse: 759.6879 - val_mae: 20.4840 - 9s/epoch - 8ms/step

Epoch 33/300

1099/1099 - 8s - loss: 702.3708 - mse: 702.3708 - mae: 18.8949 - val_loss: 755.8035 - val_mse: 755.8035 - val_mae: 20.5479 - 8s/epoch - 8ms/step

Epoch 34/300

1099/1099 - 9s - loss: 688.1999 - mse: 688.1999 - mae: 18.6163 - val_loss: 743.4545 - val_mse: 743.4545 - val_mae: 20.2455 - 9s/epoch - 8ms/step

Epoch 35/300

1099/1099 - 9s - loss: 679.3477 - mse: 679.3477 - mae: 18.4299 - val_loss: 733.0758 - val_mse: 733.0758 - val_mae: 19.8506 - 9s/epoch - 8ms/step

Epoch 36/300

1099/1099 - 9s - loss: 669.4775 - mse: 669.4775 - mae: 18.1827 - val_loss: 720.1097 - val_mse: 720.1097 - val_mae: 19.6823 - 9s/epoch - 8ms/step

Epoch 37/300

1099/1099 - 10s - loss: 657.2307 - mse: 657.2307 - mae: 17.9848 - val_loss: 724.0890 - val_mse: 724.0890 - val_mae: 19.7467 - 10s/epoch - 9ms/step

Epoch 38/300

1099/1099 - 8s - loss: 645.6097 - mse: 645.6097 - mae: 17.7306 - val_loss: 704.2900 - val_mse: 704.2900 - val_mae: 19.1736 - 8s/epoch - 8ms/step

Epoch 39/300

1099/1099 - 17s - loss: 642.1455 - mse: 642.1455 - mae: 17.6287 - val_loss: 697.7875 - val_mse: 697.7875 - val_mae: 19.0151 - 17s/epoch - 15ms/step

Epoch 40/300

1099/1099 - 11s - loss: 629.5982 - mse: 629.5982 - mae: 17.3656 - val_loss: 696.3932 - val_mse: 696.3932 - val_mae: 19.0839 - 11s/epoch - 10ms/step

Epoch 41/300

1099/1099 - 9s - loss: 623.4431 - mse: 623.4431 - mae: 17.2459 - val_loss: 682.3514 - val_mse: 682.3514 - val_mae: 18.8700 - 9s/epoch - 9ms/step
Epoch 42/300
1099/1099 - 9s - loss: 615.2922 - mse: 615.2922 - mae: 17.0991 - val_loss: 687.1910 - val_mse: 687.1910 - val_mae: 18.8694 - 9s/epoch - 8ms/step
Epoch 43/300
1099/1099 - 9s - loss: 603.6004 - mse: 603.6004 - mae: 16.8865 - val_loss: 682.9293 - val_mse: 682.9293 - val_mae: 18.7823 - 9s/epoch - 8ms/step
Epoch 44/300
1099/1099 - 9s - loss: 602.8095 - mse: 602.8095 - mae: 16.8584 - val_loss: 679.3357 - val_mse: 679.3357 - val_mae: 18.7213 - 9s/epoch - 8ms/step
Epoch 45/300
1099/1099 - 9s - loss: 597.5747 - mse: 597.5747 - mae: 16.7412 - val_loss: 665.7534 - val_mse: 665.7534 - val_mae: 18.3218 - 9s/epoch - 8ms/step
Epoch 46/300
1099/1099 - 9s - loss: 587.0026 - mse: 587.0026 - mae: 16.5434 - val_loss: 668.6752 - val_mse: 668.6752 - val_mae: 18.2038 - 9s/epoch - 8ms/step
Epoch 47/300
1099/1099 - 9s - loss: 581.9451 - mse: 581.9451 - mae: 16.4300 - val_loss: 653.7612 - val_mse: 653.7612 - val_mae: 17.5833 - 9s/epoch - 8ms/step
Epoch 48/300
1099/1099 - 9s - loss: 581.0858 - mse: 581.0858 - mae: 16.3920 - val_loss: 660.8877 - val_mse: 660.8877 - val_mae: 18.1516 - 9s/epoch - 8ms/step
Epoch 49/300
1099/1099 - 9s - loss: 574.5507 - mse: 574.5507 - mae: 16.2237 - val_loss: 657.5861 - val_mse: 657.5861 - val_mae: 18.0414 - 9s/epoch - 8ms/step
Epoch 50/300
1099/1099 - 9s - loss: 565.7435 - mse: 565.7435 - mae: 16.0836 - val_loss: 652.3870 - val_mse: 652.3870 - val_mae: 17.8461 - 9s/epoch - 8ms/step
Epoch 51/300
1099/1099 - 9s - loss: 559.0305 - mse: 559.0305 - mae: 15.9654 - val_loss: 658.6175 - val_mse: 658.6175 - val_mae: 18.0108 - 9s/epoch - 8ms/step
Epoch 52/300
1099/1099 - 9s - loss: 553.9083 - mse: 553.9083 - mae: 15.8673 - val_loss: 649.8810 - val_mse: 649.8810 - val_mae: 17.6297 - 9s/epoch - 8ms/step
Epoch 53/300
1099/1099 - 9s - loss: 548.7028 - mse: 548.7028 - mae: 15.7569 - val_loss: 643.1924 - val_mse: 643.1924 - val_mae: 17.3250 - 9s/epoch - 8ms/step
Epoch 54/300
1099/1099 - 9s - loss: 543.8834 - mse: 543.8834 - mae: 15.6740 - val_loss: 637.4684 - val_mse: 637.4684 - val_mae: 17.1760 - 9s/epoch - 8ms/step
Epoch 55/300
1099/1099 - 9s - loss: 540.9026 - mse: 540.9026 - mae: 15.5533 - val_loss: 628.2073 - val_mse: 628.2073 - val_mae: 17.0239 - 9s/epoch - 8ms/step
Epoch 56/300
1099/1099 - 9s - loss: 534.7476 - mse: 534.7476 - mae: 15.4495 - val_loss: 636.6209 - val_mse: 636.6209 - val_mae: 17.1073 - 9s/epoch - 8ms/step
Epoch 57/300
1099/1099 - 8s - loss: 526.9537 - mse: 526.9537 - mae: 15.3129 - val_loss: 633.6901 - val_mse: 633.6901 - val_mae: 17.0662 - 8s/epoch - 8ms/step
Epoch 58/300
1099/1099 - 8s - loss: 523.1292 - mse: 523.1292 - mae: 15.1981 - val_loss: 632.9583 - val_mse: 632.9583 - val_mae: 17.1169 - 8s/epoch - 8ms/step
Epoch 59/300
1099/1099 - 8s - loss: 520.6817 - mse: 520.6817 - mae: 15.1506 - val_loss: 633.4597 - val_mse: 633.4597 - val_mae: 17.0895 - 8s/epoch - 8ms/step
Epoch 60/300
1099/1099 - 9s - loss: 513.7804 - mse: 513.7804 - mae: 15.0413 - val_loss: 616.0364 - val_mse: 616.0364 - val_mae: 16.4474 - 9s/epoch - 8ms/step
Epoch 61/300
1099/1099 - 9s - loss: 510.8565 - mse: 510.8565 - mae: 14.9700 - val_loss:

625.5502 - val_mse: 625.5502 - val_mae: 16.7396 - 9s/epoch - 8ms/step
Epoch 62/300
1099/1099 - 9s - loss: 510.8627 - mse: 510.8627 - mae: 14.9646 - val_loss:
636.5859 - val_mse: 636.5859 - val_mae: 17.1450 - 9s/epoch - 8ms/step
Epoch 63/300
1099/1099 - 9s - loss: 507.2660 - mse: 507.2660 - mae: 14.8860 - val_loss:
621.9431 - val_mse: 621.9431 - val_mae: 16.5714 - 9s/epoch - 8ms/step
Epoch 64/300
1099/1099 - 10s - loss: 499.9537 - mse: 499.9537 - mae: 14.7625 - val_loss:
628.0936 - val_mse: 628.0936 - val_mae: 16.7621 - 10s/epoch - 9ms/step
Epoch 65/300
1099/1099 - 9s - loss: 498.1973 - mse: 498.1973 - mae: 14.7320 - val_loss:
621.5251 - val_mse: 621.5251 - val_mae: 16.5846 - 9s/epoch - 8ms/step
Epoch 66/300
1099/1099 - 9s - loss: 496.7740 - mse: 496.7740 - mae: 14.6535 - val_loss:
621.0718 - val_mse: 621.0718 - val_mae: 16.6454 - 9s/epoch - 8ms/step
Epoch 67/300
1099/1099 - 9s - loss: 489.3140 - mse: 489.3140 - mae: 14.5214 - val_loss:
606.5293 - val_mse: 606.5293 - val_mae: 16.2913 - 9s/epoch - 8ms/step
Epoch 68/300
1099/1099 - 9s - loss: 488.6604 - mse: 488.6604 - mae: 14.5314 - val_loss:
604.2143 - val_mse: 604.2143 - val_mae: 16.0158 - 9s/epoch - 8ms/step
Epoch 69/300
1099/1099 - 9s - loss: 485.8558 - mse: 485.8558 - mae: 14.4260 - val_loss:
612.8434 - val_mse: 612.8434 - val_mae: 16.5634 - 9s/epoch - 8ms/step
Epoch 70/300
1099/1099 - 9s - loss: 481.5226 - mse: 481.5226 - mae: 14.3855 - val_loss:
607.2191 - val_mse: 607.2191 - val_mae: 16.3421 - 9s/epoch - 8ms/step
Epoch 71/300
1099/1099 - 9s - loss: 479.3391 - mse: 479.3391 - mae: 14.3205 - val_loss:
618.8293 - val_mse: 618.8293 - val_mae: 16.6528 - 9s/epoch - 8ms/step
Epoch 72/300
1099/1099 - 9s - loss: 474.9474 - mse: 474.9474 - mae: 14.2111 - val_loss:
605.7260 - val_mse: 605.7260 - val_mae: 16.1179 - 9s/epoch - 8ms/step
Epoch 73/300
1099/1099 - 9s - loss: 474.4367 - mse: 474.4367 - mae: 14.1923 - val_loss:
608.9464 - val_mse: 608.9464 - val_mae: 16.1862 - 9s/epoch - 8ms/step
Epoch 74/300
1099/1099 - 9s - loss: 466.3401 - mse: 466.3401 - mae: 14.0800 - val_loss:
607.0006 - val_mse: 607.0006 - val_mae: 16.1684 - 9s/epoch - 8ms/step
Epoch 75/300
1099/1099 - 9s - loss: 466.7829 - mse: 466.7829 - mae: 14.0374 - val_loss:
602.3349 - val_mse: 602.3349 - val_mae: 16.1695 - 9s/epoch - 8ms/step
Epoch 76/300
1099/1099 - 9s - loss: 469.5950 - mse: 469.5950 - mae: 14.0918 - val_loss:
597.9498 - val_mse: 597.9498 - val_mae: 15.8415 - 9s/epoch - 8ms/step
Epoch 77/300
1099/1099 - 9s - loss: 465.5557 - mse: 465.5557 - mae: 14.0218 - val_loss:
594.6542 - val_mse: 594.6542 - val_mae: 15.8899 - 9s/epoch - 8ms/step
Epoch 78/300
1099/1099 - 9s - loss: 465.1595 - mse: 465.1595 - mae: 13.9716 - val_loss:
594.4121 - val_mse: 594.4121 - val_mae: 15.7286 - 9s/epoch - 8ms/step
Epoch 79/300
1099/1099 - 9s - loss: 460.1762 - mse: 460.1762 - mae: 13.9094 - val_loss:
589.3138 - val_mse: 589.3138 - val_mae: 15.6605 - 9s/epoch - 8ms/step
Epoch 80/300
1099/1099 - 9s - loss: 454.7212 - mse: 454.7212 - mae: 13.7998 - val_loss:
591.7438 - val_mse: 591.7438 - val_mae: 15.5895 - 9s/epoch - 8ms/step
Epoch 81/300
1099/1099 - 9s - loss: 453.5678 - mse: 453.5678 - mae: 13.7737 - val_loss:
589.0897 - val_mse: 589.0897 - val_mae: 15.5835 - 9s/epoch - 8ms/step

Epoch 82/300

1099/1099 - 9s - loss: 453.0638 - mse: 453.0638 - mae: 13.7821 - val_loss: 592.9932 - val_mse: 592.9932 - val_mae: 15.4525 - 9s/epoch - 8ms/step

Epoch 83/300

1099/1099 - 9s - loss: 445.6728 - mse: 445.6728 - mae: 13.6341 - val_loss: 594.5712 - val_mse: 594.5712 - val_mae: 15.4844 - 9s/epoch - 8ms/step

Epoch 84/300

1099/1099 - 9s - loss: 450.2870 - mse: 450.2870 - mae: 13.6624 - val_loss: 592.2300 - val_mse: 592.2300 - val_mae: 15.5131 - 9s/epoch - 8ms/step

Epoch 85/300

1099/1099 - 9s - loss: 446.6908 - mse: 446.6908 - mae: 13.6414 - val_loss: 595.4446 - val_mse: 595.4446 - val_mae: 15.6541 - 9s/epoch - 8ms/step

Epoch 86/300

1099/1099 - 9s - loss: 437.6017 - mse: 437.6017 - mae: 13.4952 - val_loss: 592.0041 - val_mse: 592.0041 - val_mae: 15.6120 - 9s/epoch - 8ms/step

Epoch 87/300

1099/1099 - 9s - loss: 438.8351 - mse: 438.8351 - mae: 13.4559 - val_loss: 586.1174 - val_mse: 586.1174 - val_mae: 15.3473 - 9s/epoch - 9ms/step

Epoch 88/300

1099/1099 - 8s - loss: 438.9781 - mse: 438.9781 - mae: 13.4528 - val_loss: 582.0752 - val_mse: 582.0752 - val_mae: 15.1990 - 8s/epoch - 8ms/step

Epoch 89/300

1099/1099 - 9s - loss: 430.3804 - mse: 430.3804 - mae: 13.3394 - val_loss: 580.8557 - val_mse: 580.8557 - val_mae: 15.1680 - 9s/epoch - 8ms/step

Epoch 90/300

1099/1099 - 9s - loss: 432.8158 - mse: 432.8158 - mae: 13.3521 - val_loss: 580.3282 - val_mse: 580.3282 - val_mae: 15.2429 - 9s/epoch - 9ms/step

Epoch 91/300

1099/1099 - 9s - loss: 434.1793 - mse: 434.1793 - mae: 13.3572 - val_loss: 583.2032 - val_mse: 583.2032 - val_mae: 15.4053 - 9s/epoch - 8ms/step

Epoch 92/300

1099/1099 - 8s - loss: 425.9969 - mse: 425.9969 - mae: 13.2534 - val_loss: 575.9684 - val_mse: 575.9684 - val_mae: 14.7416 - 8s/epoch - 8ms/step

Epoch 93/300

1099/1099 - 9s - loss: 423.7151 - mse: 423.7151 - mae: 13.1943 - val_loss: 577.8475 - val_mse: 577.8475 - val_mae: 15.2392 - 9s/epoch - 8ms/step

Epoch 94/300

1099/1099 - 9s - loss: 421.2535 - mse: 421.2535 - mae: 13.1353 - val_loss: 571.4086 - val_mse: 571.4086 - val_mae: 14.7331 - 9s/epoch - 8ms/step

Epoch 95/300

1099/1099 - 9s - loss: 424.2888 - mse: 424.2888 - mae: 13.1569 - val_loss: 575.4647 - val_mse: 575.4647 - val_mae: 14.9694 - 9s/epoch - 8ms/step

Epoch 96/300

1099/1099 - 9s - loss: 423.6610 - mse: 423.6610 - mae: 13.1326 - val_loss: 588.6313 - val_mse: 588.6313 - val_mae: 15.3310 - 9s/epoch - 8ms/step

Epoch 97/300

1099/1099 - 9s - loss: 420.6490 - mse: 420.6490 - mae: 13.1105 - val_loss: 576.1852 - val_mse: 576.1852 - val_mae: 15.0599 - 9s/epoch - 8ms/step

Epoch 98/300

1099/1099 - 8s - loss: 421.1063 - mse: 421.1063 - mae: 13.1159 - val_loss: 583.7602 - val_mse: 583.7602 - val_mae: 15.1125 - 8s/epoch - 8ms/step

Epoch 99/300

1099/1099 - 9s - loss: 419.2892 - mse: 419.2892 - mae: 13.0486 - val_loss: 569.2313 - val_mse: 569.2313 - val_mae: 14.7189 - 9s/epoch - 9ms/step

Epoch 100/300

1099/1099 - 9s - loss: 412.3486 - mse: 412.3486 - mae: 12.9580 - val_loss: 569.0666 - val_mse: 569.0666 - val_mae: 14.7398 - 9s/epoch - 8ms/step

Epoch 101/300

1099/1099 - 9s - loss: 413.0847 - mse: 413.0847 - mae: 12.9415 - val_loss: 572.6134 - val_mse: 572.6134 - val_mae: 14.8762 - 9s/epoch - 8ms/step

Epoch 102/300

1099/1099 - 9s - loss: 417.5892 - mse: 417.5892 - mae: 13.0103 - val_loss: 564.7835 - val_mse: 564.7835 - val_mae: 14.6430 - 9s/epoch - 8ms/step
Epoch 103/300
1099/1099 - 9s - loss: 411.0574 - mse: 411.0574 - mae: 12.8958 - val_loss: 571.0162 - val_mse: 571.0162 - val_mae: 14.5574 - 9s/epoch - 8ms/step
Epoch 104/300
1099/1099 - 9s - loss: 409.4562 - mse: 409.4562 - mae: 12.8833 - val_loss: 571.5467 - val_mse: 571.5467 - val_mae: 14.8413 - 9s/epoch - 8ms/step
Epoch 105/300
1099/1099 - 9s - loss: 404.6825 - mse: 404.6825 - mae: 12.7904 - val_loss: 565.7965 - val_mse: 565.7965 - val_mae: 14.3533 - 9s/epoch - 8ms/step
Epoch 106/300
1099/1099 - 9s - loss: 406.3268 - mse: 406.3268 - mae: 12.8449 - val_loss: 564.6174 - val_mse: 564.6174 - val_mae: 14.3724 - 9s/epoch - 8ms/step
Epoch 107/300
1099/1099 - 9s - loss: 405.8279 - mse: 405.8279 - mae: 12.8212 - val_loss: 574.4892 - val_mse: 574.4892 - val_mae: 14.8784 - 9s/epoch - 8ms/step
Epoch 108/300
1099/1099 - 9s - loss: 407.2390 - mse: 407.2390 - mae: 12.7825 - val_loss: 564.2562 - val_mse: 564.2562 - val_mae: 14.6964 - 9s/epoch - 8ms/step
Epoch 109/300
1099/1099 - 10s - loss: 400.5564 - mse: 400.5564 - mae: 12.7383 - val_loss: 557.4648 - val_mse: 557.4648 - val_mae: 14.1400 - 10s/epoch - 9ms/step
Epoch 110/300
1099/1099 - 17s - loss: 402.4985 - mse: 402.4985 - mae: 12.7255 - val_loss: 560.6191 - val_mse: 560.6191 - val_mae: 14.4652 - 17s/epoch - 15ms/step
Epoch 111/300
1099/1099 - 9s - loss: 400.0399 - mse: 400.0399 - mae: 12.6720 - val_loss: 564.8770 - val_mse: 564.8770 - val_mae: 14.4907 - 9s/epoch - 8ms/step
Epoch 112/300
1099/1099 - 9s - loss: 395.1856 - mse: 395.1856 - mae: 12.6284 - val_loss: 565.9094 - val_mse: 565.9094 - val_mae: 14.4911 - 9s/epoch - 8ms/step
Epoch 113/300
1099/1099 - 9s - loss: 397.8083 - mse: 397.8083 - mae: 12.6253 - val_loss: 565.8741 - val_mse: 565.8741 - val_mae: 14.5489 - 9s/epoch - 8ms/step
Epoch 114/300
1099/1099 - 9s - loss: 396.6734 - mse: 396.6734 - mae: 12.6028 - val_loss: 560.3052 - val_mse: 560.3052 - val_mae: 14.3809 - 9s/epoch - 8ms/step
Epoch 115/300
1099/1099 - 9s - loss: 389.8170 - mse: 389.8170 - mae: 12.4837 - val_loss: 568.4573 - val_mse: 568.4573 - val_mae: 14.5836 - 9s/epoch - 8ms/step
Epoch 116/300
1099/1099 - 9s - loss: 389.9070 - mse: 389.9070 - mae: 12.4904 - val_loss: 555.4127 - val_mse: 555.4127 - val_mae: 14.2034 - 9s/epoch - 8ms/step
Epoch 117/300
1099/1099 - 9s - loss: 387.0604 - mse: 387.0604 - mae: 12.4372 - val_loss: 561.1537 - val_mse: 561.1537 - val_mae: 14.5755 - 9s/epoch - 8ms/step
Epoch 118/300
1099/1099 - 10s - loss: 386.0965 - mse: 386.0965 - mae: 12.4499 - val_loss: 556.8687 - val_mse: 556.8687 - val_mae: 14.1209 - 10s/epoch - 9ms/step
Epoch 119/300
1099/1099 - 9s - loss: 394.4085 - mse: 394.4085 - mae: 12.5708 - val_loss: 550.7004 - val_mse: 550.7004 - val_mae: 14.2114 - 9s/epoch - 8ms/step
Epoch 120/300
1099/1099 - 9s - loss: 384.8376 - mse: 384.8376 - mae: 12.4185 - val_loss: 567.0982 - val_mse: 567.0982 - val_mae: 14.7333 - 9s/epoch - 8ms/step
Epoch 121/300
1099/1099 - 9s - loss: 380.5981 - mse: 380.5981 - mae: 12.3254 - val_loss: 554.2940 - val_mse: 554.2940 - val_mae: 14.1516 - 9s/epoch - 8ms/step
Epoch 122/300
1099/1099 - 9s - loss: 380.2068 - mse: 380.2068 - mae: 12.3139 - val_loss:

559.7746 - val_mse: 559.7746 - val_mae: 14.1451 - 9s/epoch - 8ms/step
Epoch 123/300
1099/1099 - 9s - loss: 382.5319 - mse: 382.5319 - mae: 12.3419 - val_loss:
555.0868 - val_mse: 555.0868 - val_mae: 13.9856 - 9s/epoch - 8ms/step
Epoch 124/300
1099/1099 - 9s - loss: 380.8128 - mse: 380.8128 - mae: 12.3140 - val_loss:
551.2055 - val_mse: 551.2055 - val_mae: 13.9340 - 9s/epoch - 8ms/step
Epoch 125/300
1099/1099 - 9s - loss: 376.4763 - mse: 376.4763 - mae: 12.2567 - val_loss:
558.6429 - val_mse: 558.6429 - val_mae: 14.1704 - 9s/epoch - 8ms/step
Epoch 126/300
1099/1099 - 9s - loss: 376.9927 - mse: 376.9927 - mae: 12.2473 - val_loss:
557.8055 - val_mse: 557.8055 - val_mae: 14.1574 - 9s/epoch - 8ms/step
Epoch 127/300
1099/1099 - 9s - loss: 374.9275 - mse: 374.9275 - mae: 12.1750 - val_loss:
553.6597 - val_mse: 553.6597 - val_mae: 14.0100 - 9s/epoch - 8ms/step
Epoch 128/300
1099/1099 - 9s - loss: 374.9955 - mse: 374.9955 - mae: 12.2285 - val_loss:
549.9828 - val_mse: 549.9828 - val_mae: 13.9705 - 9s/epoch - 8ms/step
Epoch 129/300
1099/1099 - 9s - loss: 375.0844 - mse: 375.0844 - mae: 12.1939 - val_loss:
550.4214 - val_mse: 550.4214 - val_mae: 14.0264 - 9s/epoch - 8ms/step
Epoch 130/300
1099/1099 - 9s - loss: 371.4454 - mse: 371.4454 - mae: 12.1191 - val_loss:
559.2820 - val_mse: 559.2820 - val_mae: 14.1755 - 9s/epoch - 8ms/step
Epoch 131/300
1099/1099 - 9s - loss: 368.1820 - mse: 368.1820 - mae: 12.1024 - val_loss:
559.9575 - val_mse: 559.9575 - val_mae: 14.0327 - 9s/epoch - 8ms/step
Epoch 132/300
1099/1099 - 10s - loss: 369.2526 - mse: 369.2526 - mae: 12.1081 - val_loss:
544.3645 - val_mse: 544.3645 - val_mae: 13.8799 - 10s/epoch - 9ms/step
Epoch 133/300
1099/1099 - 9s - loss: 368.5946 - mse: 368.5946 - mae: 12.0801 - val_loss:
559.1858 - val_mse: 559.1858 - val_mae: 14.1815 - 9s/epoch - 8ms/step
Epoch 134/300
1099/1099 - 9s - loss: 365.9876 - mse: 365.9876 - mae: 12.0237 - val_loss:
545.5040 - val_mse: 545.5040 - val_mae: 13.7468 - 9s/epoch - 8ms/step
Epoch 135/300
1099/1099 - 9s - loss: 362.5899 - mse: 362.5899 - mae: 11.9421 - val_loss:
548.8190 - val_mse: 548.8190 - val_mae: 13.7031 - 9s/epoch - 8ms/step
Epoch 136/300
1099/1099 - 9s - loss: 364.7711 - mse: 364.7711 - mae: 11.9745 - val_loss:
538.9619 - val_mse: 538.9619 - val_mae: 13.6051 - 9s/epoch - 8ms/step
Epoch 137/300
1099/1099 - 9s - loss: 363.7301 - mse: 363.7301 - mae: 11.9750 - val_loss:
550.3854 - val_mse: 550.3854 - val_mae: 13.7197 - 9s/epoch - 8ms/step
Epoch 138/300
1099/1099 - 9s - loss: 357.3473 - mse: 357.3473 - mae: 11.8815 - val_loss:
544.5272 - val_mse: 544.5272 - val_mae: 13.8413 - 9s/epoch - 8ms/step
Epoch 139/300
1099/1099 - 9s - loss: 361.1011 - mse: 361.1011 - mae: 11.9137 - val_loss:
547.5692 - val_mse: 547.5692 - val_mae: 14.0319 - 9s/epoch - 8ms/step
Epoch 140/300
1099/1099 - 9s - loss: 359.5272 - mse: 359.5272 - mae: 11.9113 - val_loss:
541.3592 - val_mse: 541.3592 - val_mae: 13.6260 - 9s/epoch - 8ms/step
Epoch 141/300
1099/1099 - 9s - loss: 362.1923 - mse: 362.1923 - mae: 11.9411 - val_loss:
548.6581 - val_mse: 548.6581 - val_mae: 13.6927 - 9s/epoch - 8ms/step
Epoch 142/300
1099/1099 - 9s - loss: 356.6537 - mse: 356.6537 - mae: 11.8747 - val_loss:
540.6080 - val_mse: 540.6080 - val_mae: 13.6729 - 9s/epoch - 8ms/step

Epoch 143/300
1099/1099 - 9s - loss: 356.5000 - mse: 356.5000 - mae: 11.8636 - val_loss: 541.6166 - val_mse: 541.6166 - val_mae: 13.6671 - 9s/epoch - 8ms/step

Epoch 144/300
1099/1099 - 9s - loss: 356.3191 - mse: 356.3191 - mae: 11.8418 - val_loss: 534.3850 - val_mse: 534.3850 - val_mae: 13.6249 - 9s/epoch - 8ms/step

Epoch 145/300
1099/1099 - 9s - loss: 349.1392 - mse: 349.1392 - mae: 11.7261 - val_loss: 548.1854 - val_mse: 548.1854 - val_mae: 13.6443 - 9s/epoch - 9ms/step

Epoch 146/300
1099/1099 - 10s - loss: 357.1372 - mse: 357.1372 - mae: 11.8299 - val_loss: 539.3022 - val_mse: 539.3022 - val_mae: 13.4676 - 10s/epoch - 9ms/step

Epoch 147/300
1099/1099 - 9s - loss: 356.2889 - mse: 356.2889 - mae: 11.8201 - val_loss: 545.4026 - val_mse: 545.4026 - val_mae: 13.9625 - 9s/epoch - 8ms/step

Epoch 148/300
1099/1099 - 9s - loss: 346.4536 - mse: 346.4536 - mae: 11.6613 - val_loss: 551.7759 - val_mse: 551.7759 - val_mae: 13.9485 - 9s/epoch - 8ms/step

Epoch 149/300
1099/1099 - 9s - loss: 351.6527 - mse: 351.6527 - mae: 11.7364 - val_loss: 548.5905 - val_mse: 548.5905 - val_mae: 13.5878 - 9s/epoch - 8ms/step

Epoch 150/300
1099/1099 - 9s - loss: 351.7559 - mse: 351.7559 - mae: 11.7492 - val_loss: 539.9276 - val_mse: 539.9276 - val_mae: 13.5176 - 9s/epoch - 8ms/step

Epoch 151/300
1099/1099 - 9s - loss: 352.2544 - mse: 352.2544 - mae: 11.7491 - val_loss: 539.2734 - val_mse: 539.2734 - val_mae: 13.4704 - 9s/epoch - 8ms/step

Epoch 152/300
1099/1099 - 9s - loss: 341.1689 - mse: 341.1689 - mae: 11.5982 - val_loss: 540.7128 - val_mse: 540.7128 - val_mae: 13.5911 - 9s/epoch - 8ms/step

Epoch 153/300
1099/1099 - 9s - loss: 348.7522 - mse: 348.7522 - mae: 11.7194 - val_loss: 541.5213 - val_mse: 541.5213 - val_mae: 13.7025 - 9s/epoch - 8ms/step

Epoch 154/300
1099/1099 - 9s - loss: 352.6519 - mse: 352.6519 - mae: 11.7672 - val_loss: 537.0009 - val_mse: 537.0009 - val_mae: 13.5761 - 9s/epoch - 8ms/step

Epoch 155/300
1099/1099 - 10s - loss: 343.4111 - mse: 343.4111 - mae: 11.6235 - val_loss: 539.5916 - val_mse: 539.5916 - val_mae: 13.9170 - 10s/epoch - 9ms/step

Epoch 156/300
1099/1099 - 9s - loss: 340.7452 - mse: 340.7452 - mae: 11.5730 - val_loss: 542.5157 - val_mse: 542.5157 - val_mae: 13.2272 - 9s/epoch - 8ms/step

Epoch 157/300
1099/1099 - 9s - loss: 346.7069 - mse: 346.7069 - mae: 11.6313 - val_loss: 533.4811 - val_mse: 533.4811 - val_mae: 13.3182 - 9s/epoch - 8ms/step

Epoch 158/300
1099/1099 - 9s - loss: 336.7197 - mse: 336.7197 - mae: 11.4972 - val_loss: 535.3875 - val_mse: 535.3875 - val_mae: 13.3146 - 9s/epoch - 8ms/step

Epoch 159/300
1099/1099 - 9s - loss: 337.3365 - mse: 337.3365 - mae: 11.4845 - val_loss: 540.4585 - val_mse: 540.4585 - val_mae: 13.4015 - 9s/epoch - 8ms/step

Epoch 160/300
1099/1099 - 9s - loss: 337.8526 - mse: 337.8526 - mae: 11.4838 - val_loss: 530.1636 - val_mse: 530.1636 - val_mae: 13.0720 - 9s/epoch - 8ms/step

Epoch 161/300
1099/1099 - 9s - loss: 335.3583 - mse: 335.3583 - mae: 11.4268 - val_loss: 535.4684 - val_mse: 535.4684 - val_mae: 13.0481 - 9s/epoch - 8ms/step

Epoch 162/300
1099/1099 - 9s - loss: 333.1937 - mse: 333.1937 - mae: 11.3826 - val_loss: 535.1964 - val_mse: 535.1964 - val_mae: 13.2529 - 9s/epoch - 8ms/step

Epoch 163/300

1099/1099 - 9s - loss: 340.3013 - mse: 340.3013 - mae: 11.5005 - val_loss: 537.9747 - val_mse: 537.9747 - val_mae: 13.2719 - 9s/epoch - 8ms/step
Epoch 164/300
1099/1099 - 9s - loss: 338.0354 - mse: 338.0354 - mae: 11.4806 - val_loss: 533.8446 - val_mse: 533.8446 - val_mae: 13.1585 - 9s/epoch - 8ms/step
Epoch 165/300
1099/1099 - 9s - loss: 339.8747 - mse: 339.8747 - mae: 11.4787 - val_loss: 533.6016 - val_mse: 533.6016 - val_mae: 13.0981 - 9s/epoch - 8ms/step
Epoch 166/300
1099/1099 - 9s - loss: 333.4033 - mse: 333.4033 - mae: 11.3948 - val_loss: 529.6846 - val_mse: 529.6846 - val_mae: 13.0703 - 9s/epoch - 8ms/step
Epoch 167/300
1099/1099 - 9s - loss: 332.2831 - mse: 332.2831 - mae: 11.3626 - val_loss: 529.9427 - val_mse: 529.9427 - val_mae: 13.2297 - 9s/epoch - 8ms/step
Epoch 168/300
1099/1099 - 10s - loss: 329.3662 - mse: 329.3662 - mae: 11.3247 - val_loss: 535.1619 - val_mse: 535.1619 - val_mae: 13.2861 - 10s/epoch - 9ms/step
Epoch 169/300
1099/1099 - 9s - loss: 331.3129 - mse: 331.3129 - mae: 11.3673 - val_loss: 539.0766 - val_mse: 539.0766 - val_mae: 13.3662 - 9s/epoch - 8ms/step
Epoch 170/300
1099/1099 - 9s - loss: 334.6724 - mse: 334.6724 - mae: 11.3998 - val_loss: 535.7458 - val_mse: 535.7458 - val_mae: 13.5692 - 9s/epoch - 8ms/step
Epoch 171/300
1099/1099 - 9s - loss: 336.3778 - mse: 336.3778 - mae: 11.4116 - val_loss: 529.7239 - val_mse: 529.7239 - val_mae: 13.3244 - 9s/epoch - 8ms/step
Epoch 172/300
1099/1099 - 10s - loss: 328.5121 - mse: 328.5121 - mae: 11.3244 - val_loss: 533.8266 - val_mse: 533.8266 - val_mae: 13.2417 - 10s/epoch - 9ms/step
Epoch 173/300
1099/1099 - 9s - loss: 329.0306 - mse: 329.0306 - mae: 11.3340 - val_loss: 524.3960 - val_mse: 524.3960 - val_mae: 13.0235 - 9s/epoch - 8ms/step
Epoch 174/300
1099/1099 - 9s - loss: 326.8526 - mse: 326.8526 - mae: 11.3211 - val_loss: 532.4634 - val_mse: 532.4634 - val_mae: 13.0720 - 9s/epoch - 8ms/step
Epoch 175/300
1099/1099 - 9s - loss: 323.6303 - mse: 323.6303 - mae: 11.2557 - val_loss: 533.0765 - val_mse: 533.0765 - val_mae: 12.9151 - 9s/epoch - 9ms/step
Epoch 176/300
1099/1099 - 9s - loss: 323.2354 - mse: 323.2354 - mae: 11.2267 - val_loss: 536.7582 - val_mse: 536.7582 - val_mae: 13.2790 - 9s/epoch - 8ms/step
Epoch 177/300
1099/1099 - 9s - loss: 322.3928 - mse: 322.3928 - mae: 11.2279 - val_loss: 543.2991 - val_mse: 543.2991 - val_mae: 13.2742 - 9s/epoch - 8ms/step
Epoch 178/300
1099/1099 - 9s - loss: 329.4641 - mse: 329.4641 - mae: 11.2891 - val_loss: 523.2891 - val_mse: 523.2891 - val_mae: 12.9410 - 9s/epoch - 8ms/step
Epoch 179/300
1099/1099 - 13s - loss: 321.0463 - mse: 321.0463 - mae: 11.1925 - val_loss: 535.9701 - val_mse: 535.9701 - val_mae: 13.2495 - 13s/epoch - 12ms/step
Epoch 180/300
1099/1099 - 11s - loss: 326.0207 - mse: 326.0207 - mae: 11.2264 - val_loss: 529.7735 - val_mse: 529.7735 - val_mae: 12.9036 - 11s/epoch - 10ms/step
Epoch 181/300
1099/1099 - 10s - loss: 327.9218 - mse: 327.9218 - mae: 11.2775 - val_loss: 527.7487 - val_mse: 527.7487 - val_mae: 12.8048 - 10s/epoch - 9ms/step
Epoch 182/300
1099/1099 - 9s - loss: 322.1943 - mse: 322.1943 - mae: 11.1706 - val_loss: 536.1139 - val_mse: 536.1139 - val_mae: 13.1517 - 9s/epoch - 8ms/step
Epoch 183/300
1099/1099 - 9s - loss: 318.9508 - mse: 318.9508 - mae: 11.1242 - val_loss:

524.0286 - val_mse: 524.0286 - val_mae: 12.6223 - 9s/epoch - 8ms/step
Epoch 184/300
1099/1099 - 9s - loss: 319.9847 - mse: 319.9847 - mae: 11.1560 - val_loss:
533.8649 - val_mse: 533.8649 - val_mae: 13.1206 - 9s/epoch - 8ms/step
Epoch 185/300
1099/1099 - 9s - loss: 318.4498 - mse: 318.4498 - mae: 11.1330 - val_loss:
525.7281 - val_mse: 525.7281 - val_mae: 12.8861 - 9s/epoch - 8ms/step
Epoch 186/300
1099/1099 - 10s - loss: 315.0087 - mse: 315.0087 - mae: 11.0494 - val_loss:
524.0748 - val_mse: 524.0748 - val_mae: 12.8864 - 10s/epoch - 9ms/step
Epoch 187/300
1099/1099 - 9s - loss: 315.2444 - mse: 315.2444 - mae: 11.0314 - val_loss:
535.1678 - val_mse: 535.1678 - val_mae: 13.0203 - 9s/epoch - 8ms/step
Epoch 188/300
1099/1099 - 9s - loss: 318.2451 - mse: 318.2451 - mae: 11.1046 - val_loss:
526.6638 - val_mse: 526.6638 - val_mae: 12.7549 - 9s/epoch - 8ms/step
Epoch 189/300
1099/1099 - 9s - loss: 311.7537 - mse: 311.7537 - mae: 10.9695 - val_loss:
538.0087 - val_mse: 538.0087 - val_mae: 12.9435 - 9s/epoch - 8ms/step
Epoch 190/300
1099/1099 - 9s - loss: 315.7914 - mse: 315.7914 - mae: 11.0852 - val_loss:
522.9172 - val_mse: 522.9172 - val_mae: 12.7243 - 9s/epoch - 8ms/step
Epoch 191/300
1099/1099 - 9s - loss: 316.0918 - mse: 316.0918 - mae: 11.0527 - val_loss:
526.4165 - val_mse: 526.4165 - val_mae: 12.8838 - 9s/epoch - 8ms/step
Epoch 192/300
1099/1099 - 9s - loss: 310.3217 - mse: 310.3217 - mae: 10.9913 - val_loss:
529.5690 - val_mse: 529.5690 - val_mae: 12.9697 - 9s/epoch - 8ms/step
Epoch 193/300
1099/1099 - 9s - loss: 314.6762 - mse: 314.6762 - mae: 11.0432 - val_loss:
524.5898 - val_mse: 524.5898 - val_mae: 12.6779 - 9s/epoch - 8ms/step
Epoch 194/300
1099/1099 - 9s - loss: 310.5820 - mse: 310.5820 - mae: 10.9868 - val_loss:
532.4343 - val_mse: 532.4343 - val_mae: 12.8419 - 9s/epoch - 8ms/step
Epoch 195/300
1099/1099 - 9s - loss: 310.7597 - mse: 310.7597 - mae: 10.9582 - val_loss:
518.7574 - val_mse: 518.7574 - val_mae: 12.5289 - 9s/epoch - 8ms/step
Epoch 196/300
1099/1099 - 9s - loss: 307.6224 - mse: 307.6224 - mae: 10.8839 - val_loss:
516.2957 - val_mse: 516.2957 - val_mae: 12.6747 - 9s/epoch - 8ms/step
Epoch 197/300
1099/1099 - 10s - loss: 314.9184 - mse: 314.9184 - mae: 11.0197 - val_loss:
516.0613 - val_mse: 516.0613 - val_mae: 12.3936 - 10s/epoch - 9ms/step
Epoch 198/300
1099/1099 - 9s - loss: 314.9012 - mse: 314.9012 - mae: 11.0504 - val_loss:
518.5687 - val_mse: 518.5687 - val_mae: 12.5193 - 9s/epoch - 8ms/step
Epoch 199/300
1099/1099 - 9s - loss: 308.1686 - mse: 308.1686 - mae: 10.9167 - val_loss:
517.6878 - val_mse: 517.6878 - val_mae: 12.5542 - 9s/epoch - 8ms/step
Epoch 200/300
1099/1099 - 9s - loss: 302.2669 - mse: 302.2669 - mae: 10.8453 - val_loss:
516.0865 - val_mse: 516.0865 - val_mae: 12.4664 - 9s/epoch - 8ms/step
Epoch 201/300
1099/1099 - 9s - loss: 305.1717 - mse: 305.1717 - mae: 10.8559 - val_loss:
524.1097 - val_mse: 524.1097 - val_mae: 12.5264 - 9s/epoch - 8ms/step
Epoch 202/300
1099/1099 - 9s - loss: 305.9128 - mse: 305.9128 - mae: 10.8413 - val_loss:
519.4032 - val_mse: 519.4032 - val_mae: 12.4789 - 9s/epoch - 8ms/step
Epoch 203/300
1099/1099 - 9s - loss: 308.3293 - mse: 308.3293 - mae: 10.8760 - val_loss:
525.8481 - val_mse: 525.8481 - val_mae: 12.8129 - 9s/epoch - 8ms/step

Epoch 204/300

1099/1099 - 9s - loss: 306.5614 - mse: 306.5614 - mae: 10.8958 - val_loss: 525.1072 - val_mse: 525.1072 - val_mae: 12.5789 - 9s/epoch - 8ms/step

Epoch 205/300

1099/1099 - 9s - loss: 303.2067 - mse: 303.2067 - mae: 10.8296 - val_loss: 515.5260 - val_mse: 515.5260 - val_mae: 12.4461 - 9s/epoch - 8ms/step

Epoch 206/300

1099/1099 - 9s - loss: 303.5400 - mse: 303.5400 - mae: 10.8269 - val_loss: 512.2003 - val_mse: 512.2003 - val_mae: 12.2829 - 9s/epoch - 8ms/step

Epoch 207/300

1099/1099 - 9s - loss: 298.6651 - mse: 298.6651 - mae: 10.7310 - val_loss: 521.2186 - val_mse: 521.2186 - val_mae: 12.4128 - 9s/epoch - 8ms/step

Epoch 208/300

1099/1099 - 9s - loss: 302.9556 - mse: 302.9556 - mae: 10.7604 - val_loss: 515.0061 - val_mse: 515.0061 - val_mae: 12.1970 - 9s/epoch - 8ms/step

Epoch 209/300

1099/1099 - 10s - loss: 299.5012 - mse: 299.5012 - mae: 10.7398 - val_loss: 519.3391 - val_mse: 519.3391 - val_mae: 12.4129 - 10s/epoch - 9ms/step

Epoch 210/300

1099/1099 - 9s - loss: 304.4995 - mse: 304.4995 - mae: 10.7939 - val_loss: 520.7670 - val_mse: 520.7670 - val_mae: 12.5362 - 9s/epoch - 8ms/step

Epoch 211/300

1099/1099 - 9s - loss: 300.6449 - mse: 300.6449 - mae: 10.6883 - val_loss: 516.4608 - val_mse: 516.4608 - val_mae: 12.3869 - 9s/epoch - 8ms/step

Epoch 212/300

1099/1099 - 9s - loss: 295.5244 - mse: 295.5244 - mae: 10.6471 - val_loss: 521.7621 - val_mse: 521.7621 - val_mae: 12.3831 - 9s/epoch - 8ms/step

Epoch 213/300

1099/1099 - 10s - loss: 298.4520 - mse: 298.4520 - mae: 10.6754 - val_loss: 517.2720 - val_mse: 517.2720 - val_mae: 12.5526 - 10s/epoch - 9ms/step

Epoch 214/300

1099/1099 - 9s - loss: 295.0892 - mse: 295.0892 - mae: 10.6300 - val_loss: 515.7536 - val_mse: 515.7536 - val_mae: 12.2659 - 9s/epoch - 9ms/step

Epoch 215/300

1099/1099 - 9s - loss: 293.8480 - mse: 293.8480 - mae: 10.5681 - val_loss: 509.3891 - val_mse: 509.3891 - val_mae: 12.1912 - 9s/epoch - 8ms/step

Epoch 216/300

1099/1099 - 9s - loss: 294.9461 - mse: 294.9461 - mae: 10.6008 - val_loss: 511.8404 - val_mse: 511.8404 - val_mae: 12.1768 - 9s/epoch - 8ms/step

Epoch 217/300

1099/1099 - 9s - loss: 293.7163 - mse: 293.7163 - mae: 10.6046 - val_loss: 518.3167 - val_mse: 518.3167 - val_mae: 12.4053 - 9s/epoch - 8ms/step

Epoch 218/300

1099/1099 - 10s - loss: 294.2997 - mse: 294.2997 - mae: 10.5989 - val_loss: 514.6874 - val_mse: 514.6874 - val_mae: 12.1561 - 10s/epoch - 9ms/step

Epoch 219/300

1099/1099 - 10s - loss: 294.2521 - mse: 294.2521 - mae: 10.6314 - val_loss: 511.5397 - val_mse: 511.5397 - val_mae: 12.2010 - 10s/epoch - 9ms/step

Epoch 220/300

1099/1099 - 9s - loss: 290.4111 - mse: 290.4111 - mae: 10.5561 - val_loss: 513.6531 - val_mse: 513.6531 - val_mae: 12.2247 - 9s/epoch - 8ms/step

Epoch 221/300

1099/1099 - 9s - loss: 295.4888 - mse: 295.4888 - mae: 10.6355 - val_loss: 516.1520 - val_mse: 516.1520 - val_mae: 12.3393 - 9s/epoch - 8ms/step

Epoch 222/300

1099/1099 - 9s - loss: 293.7618 - mse: 293.7618 - mae: 10.5672 - val_loss: 515.2380 - val_mse: 515.2380 - val_mae: 12.3367 - 9s/epoch - 8ms/step

Epoch 223/300

1099/1099 - 9s - loss: 291.2698 - mse: 291.2698 - mae: 10.5806 - val_loss: 508.3618 - val_mse: 508.3618 - val_mae: 12.0594 - 9s/epoch - 8ms/step

Epoch 224/300

1099/1099 - 9s - loss: 287.3468 - mse: 287.3468 - mae: 10.4854 - val_loss: 510.9046 - val_mse: 510.9046 - val_mae: 12.0574 - 9s/epoch - 8ms/step
Epoch 225/300
1099/1099 - 9s - loss: 285.8598 - mse: 285.8598 - mae: 10.4509 - val_loss: 519.0903 - val_mse: 519.0903 - val_mae: 12.3662 - 9s/epoch - 8ms/step
Epoch 226/300
1099/1099 - 9s - loss: 292.9332 - mse: 292.9332 - mae: 10.5380 - val_loss: 515.1440 - val_mse: 515.1440 - val_mae: 12.1622 - 9s/epoch - 8ms/step
Epoch 227/300
1099/1099 - 9s - loss: 283.0947 - mse: 283.0947 - mae: 10.3966 - val_loss: 506.5170 - val_mse: 506.5170 - val_mae: 11.9871 - 9s/epoch - 8ms/step
Epoch 228/300
1099/1099 - 9s - loss: 284.9822 - mse: 284.9822 - mae: 10.3983 - val_loss: 506.8776 - val_mse: 506.8776 - val_mae: 12.0440 - 9s/epoch - 8ms/step
Epoch 229/300
1099/1099 - 9s - loss: 289.4203 - mse: 289.4203 - mae: 10.4556 - val_loss: 511.2195 - val_mse: 511.2195 - val_mae: 12.0902 - 9s/epoch - 8ms/step
Epoch 230/300
1099/1099 - 9s - loss: 281.4487 - mse: 281.4487 - mae: 10.3470 - val_loss: 510.6892 - val_mse: 510.6892 - val_mae: 12.0959 - 9s/epoch - 8ms/step
Epoch 231/300
1099/1099 - 9s - loss: 283.9278 - mse: 283.9278 - mae: 10.3913 - val_loss: 502.3643 - val_mse: 502.3643 - val_mae: 11.8632 - 9s/epoch - 8ms/step
Epoch 232/300
1099/1099 - 9s - loss: 280.6975 - mse: 280.6975 - mae: 10.3104 - val_loss: 499.9571 - val_mse: 499.9571 - val_mae: 11.8206 - 9s/epoch - 8ms/step
Epoch 233/300
1099/1099 - 9s - loss: 276.4212 - mse: 276.4212 - mae: 10.2267 - val_loss: 509.8306 - val_mse: 509.8306 - val_mae: 11.8917 - 9s/epoch - 8ms/step
Epoch 234/300
1099/1099 - 9s - loss: 283.0117 - mse: 283.0117 - mae: 10.3619 - val_loss: 500.8110 - val_mse: 500.8110 - val_mae: 12.0443 - 9s/epoch - 8ms/step
Epoch 235/300
1099/1099 - 9s - loss: 282.6183 - mse: 282.6183 - mae: 10.3308 - val_loss: 505.5912 - val_mse: 505.5912 - val_mae: 12.1514 - 9s/epoch - 8ms/step
Epoch 236/300
1099/1099 - 10s - loss: 278.9891 - mse: 278.9891 - mae: 10.2833 - val_loss: 503.8743 - val_mse: 503.8743 - val_mae: 11.9908 - 10s/epoch - 9ms/step
Epoch 237/300
1099/1099 - 9s - loss: 273.4027 - mse: 273.4027 - mae: 10.1938 - val_loss: 514.2939 - val_mse: 514.2939 - val_mae: 12.0523 - 9s/epoch - 8ms/step
Epoch 238/300
1099/1099 - 9s - loss: 276.7922 - mse: 276.7922 - mae: 10.2279 - val_loss: 510.0482 - val_mse: 510.0482 - val_mae: 12.0152 - 9s/epoch - 9ms/step
Epoch 239/300
1099/1099 - 9s - loss: 276.4099 - mse: 276.4099 - mae: 10.2646 - val_loss: 509.9658 - val_mse: 509.9658 - val_mae: 11.8347 - 9s/epoch - 8ms/step
Epoch 240/300
1099/1099 - 10s - loss: 272.4333 - mse: 272.4333 - mae: 10.1559 - val_loss: 501.8195 - val_mse: 501.8195 - val_mae: 11.8620 - 10s/epoch - 9ms/step
Epoch 241/300
1099/1099 - 9s - loss: 277.6859 - mse: 277.6859 - mae: 10.2101 - val_loss: 503.9290 - val_mse: 503.9290 - val_mae: 11.8337 - 9s/epoch - 8ms/step
Epoch 242/300
1099/1099 - 9s - loss: 268.0371 - mse: 268.0371 - mae: 10.0387 - val_loss: 504.3067 - val_mse: 504.3067 - val_mae: 11.7817 - 9s/epoch - 8ms/step
Epoch 243/300
1099/1099 - 12s - loss: 273.0778 - mse: 273.0778 - mae: 10.1399 - val_loss: 506.6946 - val_mse: 506.6946 - val_mae: 11.8960 - 12s/epoch - 11ms/step
Epoch 244/300
1099/1099 - 14s - loss: 274.8676 - mse: 274.8676 - mae: 10.1699 - val_loss:

s: 502.1089 - val_mse: 502.1089 - val_mae: 11.9017 - 14s/epoch - 13ms/step
Epoch 245/300
1099/1099 - 11s - loss: 271.2878 - mse: 271.2878 - mae: 10.1078 - val_loss:
s: 497.6656 - val_mse: 497.6656 - val_mae: 11.9180 - 11s/epoch - 10ms/step
Epoch 246/300
1099/1099 - 9s - loss: 265.0642 - mse: 265.0642 - mae: 10.0271 - val_loss:
504.6465 - val_mse: 504.6465 - val_mae: 11.6872 - 9s/epoch - 9ms/step
Epoch 247/300
1099/1099 - 9s - loss: 269.7279 - mse: 269.7279 - mae: 10.0759 - val_loss:
503.8042 - val_mse: 503.8042 - val_mae: 11.8155 - 9s/epoch - 8ms/step
Epoch 248/300
1099/1099 - 9s - loss: 267.5490 - mse: 267.5490 - mae: 10.0632 - val_loss:
510.8550 - val_mse: 510.8550 - val_mae: 11.8293 - 9s/epoch - 8ms/step
Epoch 249/300
1099/1099 - 9s - loss: 269.8728 - mse: 269.8728 - mae: 10.0671 - val_loss:
504.9209 - val_mse: 504.9209 - val_mae: 11.7837 - 9s/epoch - 8ms/step
Epoch 250/300
1099/1099 - 9s - loss: 274.8593 - mse: 274.8593 - mae: 10.1389 - val_loss:
501.8802 - val_mse: 501.8802 - val_mae: 11.9925 - 9s/epoch - 8ms/step
Epoch 251/300
1099/1099 - 10s - loss: 269.8032 - mse: 269.8032 - mae: 10.0558 - val_loss:
s: 509.4117 - val_mse: 509.4117 - val_mae: 11.8860 - 10s/epoch - 9ms/step
Epoch 252/300
1099/1099 - 9s - loss: 267.5594 - mse: 267.5594 - mae: 10.0190 - val_loss:
503.2235 - val_mse: 503.2235 - val_mae: 11.8155 - 9s/epoch - 8ms/step
Epoch 253/300
1099/1099 - 9s - loss: 268.0284 - mse: 268.0284 - mae: 10.0236 - val_loss:
503.7684 - val_mse: 503.7684 - val_mae: 11.6912 - 9s/epoch - 9ms/step
Epoch 254/300
1099/1099 - 9s - loss: 268.9388 - mse: 268.9388 - mae: 10.0237 - val_loss:
502.2617 - val_mse: 502.2617 - val_mae: 11.7572 - 9s/epoch - 8ms/step
Epoch 255/300
1099/1099 - 9s - loss: 268.0262 - mse: 268.0262 - mae: 10.0252 - val_loss:
506.2819 - val_mse: 506.2819 - val_mae: 11.9417 - 9s/epoch - 8ms/step
Epoch 256/300
1099/1099 - 9s - loss: 274.4170 - mse: 274.4170 - mae: 10.1081 - val_loss:
507.8145 - val_mse: 507.8145 - val_mae: 11.8603 - 9s/epoch - 8ms/step
Epoch 257/300
1099/1099 - 9s - loss: 275.5645 - mse: 275.5645 - mae: 10.1222 - val_loss:
506.9027 - val_mse: 506.9027 - val_mae: 11.8377 - 9s/epoch - 8ms/step
Epoch 258/300
1099/1099 - 9s - loss: 267.7637 - mse: 267.7637 - mae: 10.0286 - val_loss:
508.9046 - val_mse: 508.9046 - val_mae: 11.9103 - 9s/epoch - 8ms/step
Epoch 259/300
1099/1099 - 8s - loss: 267.5609 - mse: 267.5609 - mae: 10.0188 - val_loss:
500.2694 - val_mse: 500.2694 - val_mae: 11.5985 - 8s/epoch - 8ms/step
Epoch 260/300
1099/1099 - 9s - loss: 267.8717 - mse: 267.8717 - mae: 9.9882 - val_loss:
508.0703 - val_mse: 508.0703 - val_mae: 12.0624 - 9s/epoch - 9ms/step
Epoch 261/300
1099/1099 - 9s - loss: 263.6337 - mse: 263.6337 - mae: 9.9748 - val_loss:
500.9661 - val_mse: 500.9661 - val_mae: 11.8693 - 9s/epoch - 8ms/step
Epoch 262/300
1099/1099 - 9s - loss: 266.2018 - mse: 266.2018 - mae: 9.9545 - val_loss:
510.7576 - val_mse: 510.7576 - val_mae: 11.8360 - 9s/epoch - 8ms/step
Epoch 263/300
1099/1099 - 9s - loss: 262.2680 - mse: 262.2680 - mae: 9.9328 - val_loss:
494.4075 - val_mse: 494.4075 - val_mae: 11.4997 - 9s/epoch - 9ms/step
Epoch 264/300
1099/1099 - 9s - loss: 260.6255 - mse: 260.6255 - mae: 9.9168 - val_loss:
503.1224 - val_mse: 503.1224 - val_mae: 11.7042 - 9s/epoch - 8ms/step

Epoch 265/300
1099/1099 - 9s - loss: 260.6905 - mse: 260.6905 - mae: 9.8550 - val_loss: 498.2226 - val_mse: 498.2226 - val_mae: 11.5192 - 9s/epoch - 8ms/step

Epoch 266/300
1099/1099 - 9s - loss: 263.1281 - mse: 263.1281 - mae: 9.9111 - val_loss: 500.4494 - val_mse: 500.4494 - val_mae: 11.5724 - 9s/epoch - 8ms/step

Epoch 267/300
1099/1099 - 9s - loss: 262.9058 - mse: 262.9058 - mae: 9.9359 - val_loss: 497.9618 - val_mse: 497.9618 - val_mae: 11.6870 - 9s/epoch - 8ms/step

Epoch 268/300
1099/1099 - 9s - loss: 260.7508 - mse: 260.7508 - mae: 9.8864 - val_loss: 507.9700 - val_mse: 507.9700 - val_mae: 11.8011 - 9s/epoch - 8ms/step

Epoch 269/300
1099/1099 - 9s - loss: 260.9876 - mse: 260.9876 - mae: 9.8917 - val_loss: 507.1066 - val_mse: 507.1066 - val_mae: 11.5743 - 9s/epoch - 8ms/step

Epoch 270/300
1099/1099 - 9s - loss: 257.5834 - mse: 257.5834 - mae: 9.8152 - val_loss: 501.6868 - val_mse: 501.6868 - val_mae: 11.7981 - 9s/epoch - 9ms/step

Epoch 271/300
1099/1099 - 9s - loss: 256.9724 - mse: 256.9724 - mae: 9.8228 - val_loss: 504.9720 - val_mse: 504.9720 - val_mae: 11.6388 - 9s/epoch - 8ms/step

Epoch 272/300
1099/1099 - 9s - loss: 261.7279 - mse: 261.7279 - mae: 9.8909 - val_loss: 493.9909 - val_mse: 493.9909 - val_mae: 11.5465 - 9s/epoch - 8ms/step

Epoch 273/300
1099/1099 - 9s - loss: 256.3964 - mse: 256.3964 - mae: 9.8062 - val_loss: 502.8134 - val_mse: 502.8134 - val_mae: 11.5075 - 9s/epoch - 8ms/step

Epoch 274/300
1099/1099 - 9s - loss: 263.7243 - mse: 263.7243 - mae: 9.9054 - val_loss: 499.9871 - val_mse: 499.9871 - val_mae: 11.5886 - 9s/epoch - 8ms/step

Epoch 275/300
1099/1099 - 9s - loss: 256.1672 - mse: 256.1672 - mae: 9.7868 - val_loss: 505.3535 - val_mse: 505.3535 - val_mae: 11.5847 - 9s/epoch - 8ms/step

Epoch 276/300
1099/1099 - 9s - loss: 258.8184 - mse: 258.8184 - mae: 9.8266 - val_loss: 501.2555 - val_mse: 501.2555 - val_mae: 11.7085 - 9s/epoch - 8ms/step

Epoch 277/300
1099/1099 - 9s - loss: 258.3631 - mse: 258.3631 - mae: 9.8280 - val_loss: 501.4131 - val_mse: 501.4131 - val_mae: 11.8766 - 9s/epoch - 8ms/step

Epoch 278/300
1099/1099 - 10s - loss: 256.2561 - mse: 256.2561 - mae: 9.7753 - val_loss: 503.3647 - val_mse: 503.3647 - val_mae: 11.7554 - 10s/epoch - 9ms/step

Epoch 279/300
1099/1099 - 9s - loss: 250.8340 - mse: 250.8340 - mae: 9.6921 - val_loss: 495.6674 - val_mse: 495.6674 - val_mae: 11.4859 - 9s/epoch - 8ms/step

Epoch 280/300
1099/1099 - 9s - loss: 255.4832 - mse: 255.4832 - mae: 9.7607 - val_loss: 494.8235 - val_mse: 494.8235 - val_mae: 11.3836 - 9s/epoch - 8ms/step

Epoch 281/300
1099/1099 - 10s - loss: 252.9193 - mse: 252.9193 - mae: 9.7229 - val_loss: 498.0021 - val_mse: 498.0021 - val_mae: 11.4526 - 10s/epoch - 9ms/step

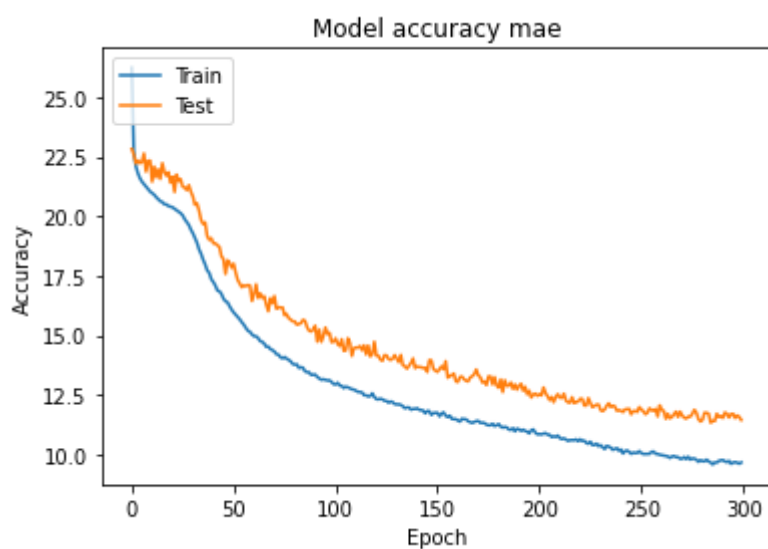
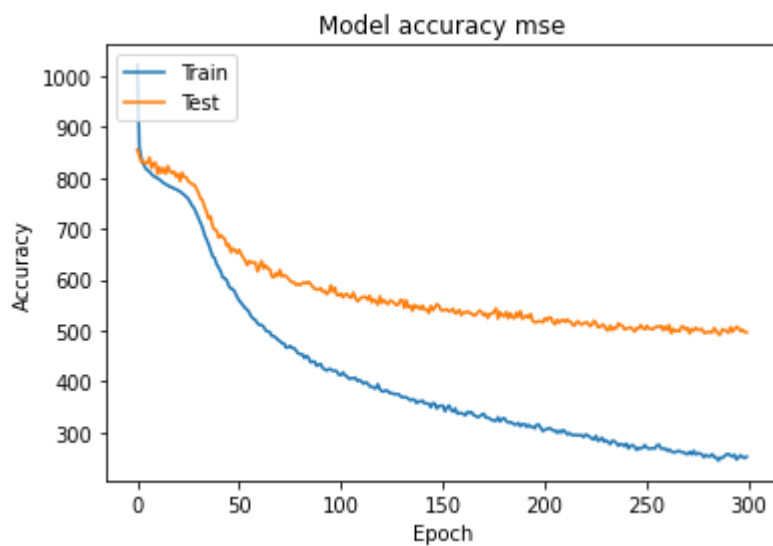
Epoch 282/300
1099/1099 - 10s - loss: 252.3950 - mse: 252.3950 - mae: 9.7104 - val_loss: 496.6890 - val_mse: 496.6890 - val_mae: 11.7511 - 10s/epoch - 9ms/step

Epoch 283/300
1099/1099 - 9s - loss: 257.0122 - mse: 257.0122 - mae: 9.7816 - val_loss: 495.6813 - val_mse: 495.6813 - val_mae: 11.7497 - 9s/epoch - 8ms/step

Epoch 284/300
1099/1099 - 10s - loss: 251.0080 - mse: 251.0080 - mae: 9.7080 - val_loss: 505.0247 - val_mse: 505.0247 - val_mae: 11.7095 - 10s/epoch - 9ms/step

Epoch 285/300

1099/1099 - 9s - loss: 251.0114 - mse: 251.0114 - mae: 9.6643 - val_loss: 499.8742 - val_mse: 499.8742 - val_mae: 11.3318 - 9s/epoch - 8ms/step
Epoch 286/300
1099/1099 - 9s - loss: 244.2042 - mse: 244.2042 - mae: 9.5795 - val_loss: 492.5712 - val_mse: 492.5712 - val_mae: 11.4057 - 9s/epoch - 9ms/step
Epoch 287/300
1099/1099 - 9s - loss: 250.1693 - mse: 250.1693 - mae: 9.6657 - val_loss: 492.1859 - val_mse: 492.1859 - val_mae: 11.4032 - 9s/epoch - 8ms/step
Epoch 288/300
1099/1099 - 10s - loss: 249.3291 - mse: 249.3291 - mae: 9.6587 - val_loss: 502.3750 - val_mse: 502.3750 - val_mae: 11.7113 - 10s/epoch - 9ms/step
Epoch 289/300
1099/1099 - 9s - loss: 253.0388 - mse: 253.0388 - mae: 9.7280 - val_loss: 500.9734 - val_mse: 500.9734 - val_mae: 11.5664 - 9s/epoch - 9ms/step
Epoch 290/300
1099/1099 - 9s - loss: 256.3692 - mse: 256.3692 - mae: 9.7521 - val_loss: 498.5526 - val_mse: 498.5526 - val_mae: 11.6161 - 9s/epoch - 8ms/step
Epoch 291/300
1099/1099 - 10s - loss: 257.3838 - mse: 257.3838 - mae: 9.7640 - val_loss: 495.3896 - val_mse: 495.3896 - val_mae: 11.5305 - 10s/epoch - 9ms/step
Epoch 292/300
1099/1099 - 9s - loss: 254.2761 - mse: 254.2761 - mae: 9.7081 - val_loss: 506.7005 - val_mse: 506.7005 - val_mae: 11.7651 - 9s/epoch - 9ms/step
Epoch 293/300
1099/1099 - 9s - loss: 252.2094 - mse: 252.2094 - mae: 9.6767 - val_loss: 497.3764 - val_mse: 497.3764 - val_mae: 11.7043 - 9s/epoch - 8ms/step
Epoch 294/300
1099/1099 - 10s - loss: 255.8993 - mse: 255.8993 - mae: 9.7304 - val_loss: 502.7736 - val_mse: 502.7736 - val_mae: 11.5469 - 10s/epoch - 9ms/step
Epoch 295/300
1099/1099 - 9s - loss: 246.4120 - mse: 246.4120 - mae: 9.6072 - val_loss: 507.2583 - val_mse: 507.2583 - val_mae: 11.7027 - 9s/epoch - 8ms/step
Epoch 296/300
1099/1099 - 9s - loss: 250.9308 - mse: 250.9308 - mae: 9.6571 - val_loss: 504.6384 - val_mse: 504.6384 - val_mae: 11.7024 - 9s/epoch - 8ms/step
Epoch 297/300
1099/1099 - 9s - loss: 254.8535 - mse: 254.8535 - mae: 9.6802 - val_loss: 498.5304 - val_mse: 498.5304 - val_mae: 11.5274 - 9s/epoch - 8ms/step
Epoch 298/300
1099/1099 - 9s - loss: 251.2352 - mse: 251.2352 - mae: 9.6544 - val_loss: 501.6738 - val_mse: 501.6738 - val_mae: 11.6417 - 9s/epoch - 8ms/step
Epoch 299/300
1099/1099 - 9s - loss: 249.1095 - mse: 249.1095 - mae: 9.6089 - val_loss: 496.4703 - val_mse: 496.4703 - val_mae: 11.5765 - 9s/epoch - 8ms/step
Epoch 300/300
1099/1099 - 9s - loss: 251.9662 - mse: 251.9662 - mae: 9.6653 - val_loss: 496.1616 - val_mse: 496.1616 - val_mae: 11.4469 - 9s/epoch - 8ms/step



MUSIC MSE: 1375.568

MUSIC MAE: 21.1539

Out of range MUSIC prediction: 0

In []:

```
print("Combined phase and magnitude 1D CNN")

shape=(640,1)
filters=(64,64)
layers=(100, )
epochs = 100

phase = create_1d_cnn(shape, False, filters, layers, 'relu')
magnitude = create_1d_cnn(shape, False, filters, layers, 'relu')

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
x=[x_train_magnitude, x_train_phase], y=y_train,
  validation_data=([x_test_magnitude, x_test_phase], y_test),
  epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)

comparison = MUSIC_metrics(data_split[5])
print("MUSIC MSE: ", comparison[1])
print("MUSIC MAE: ", comparison[0])
print("Out of range MUSIC prediction: ", len(comparison[2]))
```

Combined phase and magnitude 1D CNN

Epoch 1/100

1099/1099 - 124s - loss: 1220.7885 - mse: 1220.7885 - mae: 30.2648 - val_loss: 1219.1746 - val_mse: 1219.1746 - val_mae: 30.2258 - 124s/epoch - 113ms/step

Epoch 2/100

1099/1099 - 122s - loss: 1220.5573 - mse: 1220.5573 - mae: 30.2630 - val_loss: 1219.1036 - val_mse: 1219.1036 - val_mae: 30.2252 - 122s/epoch - 111ms/step

Epoch 3/100

1099/1099 - 121s - loss: 1178.0038 - mse: 1178.0038 - mae: 29.4432 - val_loss: 1010.7211 - val_mse: 1010.7211 - val_mae: 26.5587 - 121s/epoch - 110ms/step

Epoch 4/100

1099/1099 - 122s - loss: 1021.4159 - mse: 1021.4159 - mae: 26.3555 - val_loss: 941.4464 - val_mse: 941.4464 - val_mae: 25.2038 - 122s/epoch - 111ms/step

Epoch 5/100

1099/1099 - 121s - loss: 975.1997 - mse: 975.1997 - mae: 25.3933 - val_loss: 902.6898 - val_mse: 902.6898 - val_mae: 24.2557 - 121s/epoch - 110ms/step

Epoch 6/100

1099/1099 - 121s - loss: 947.4227 - mse: 947.4227 - mae: 24.8150 - val_loss: 882.8874 - val_mse: 882.8874 - val_mae: 23.9157 - 121s/epoch - 110ms/step

Epoch 7/100

1099/1099 - 121s - loss: 919.3404 - mse: 919.3404 - mae: 24.2317 - val_loss: 857.3107 - val_mse: 857.3107 - val_mae: 23.2801 - 121s/epoch - 110ms/step

Epoch 8/100

1099/1099 - 121s - loss: 896.7301 - mse: 896.7301 - mae: 23.7584 - val_loss: 838.5197 - val_mse: 838.5197 - val_mae: 22.7927 - 121s/epoch - 110ms/step

Epoch 9/100

1099/1099 - 121s - loss: 877.3640 - mse: 877.3640 - mae: 23.3636 - val_loss: 822.7529 - val_mse: 822.7529 - val_mae: 22.3153 - 121s/epoch - 110ms/step

Epoch 10/100

1099/1099 - 121s - loss: 860.5796 - mse: 860.5796 - mae: 22.9772 - val_loss: 822.8441 - val_mse: 822.8441 - val_mae: 22.3612 - 121s/epoch - 110ms/step

Epoch 11/100

1099/1099 - 122s - loss: 842.6853 - mse: 842.6853 - mae: 22.6087 - val_loss: 795.9397 - val_mse: 795.9397 - val_mae: 21.4368 - 122s/epoch - 111ms/step

Epoch 12/100

1099/1099 - 122s - loss: 832.0893 - mse: 832.0893 - mae: 22.3873 - val_loss: 804.6470 - val_mse: 804.6470 - val_mae: 21.8973 - 122s/epoch - 111ms/step

Epoch 13/100

1099/1099 - 123s - loss: 822.1264 - mse: 822.1264 - mae: 22.1642 - val_loss: 793.2888 - val_mse: 793.2888 - val_mae: 21.4496 - 123s/epoch - 112ms/step

Epoch 14/100

1099/1099 - 123s - loss: 811.7425 - mse: 811.7425 - mae: 21.9459 - val_loss: 791.2841 - val_mse: 791.2841 - val_mae: 21.5694 - 123s/epoch - 112ms/step

Epoch 15/100

1099/1099 - 123s - loss: 803.8261 - mse: 803.8261 - mae: 21.7612 - val_loss: 773.9667 - val_mse: 773.9667 - val_mae: 20.9762 - 123s/epoch - 112ms/step

Epoch 16/100

1099/1099 - 122s - loss: 794.2652 - mse: 794.2652 - mae: 21.5845 - val_loss: 777.9991 - val_mse: 777.9991 - val_mae: 21.2406 - 122s/epoch - 111ms/st
ep

Epoch 17/100

1099/1099 - 121s - loss: 785.1017 - mse: 785.1017 - mae: 21.3796 - val_loss: 773.6901 - val_mse: 773.6901 - val_mae: 21.2202 - 121s/epoch - 110ms/st
ep

Epoch 18/100

1099/1099 - 121s - loss: 774.4182 - mse: 774.4182 - mae: 21.1729 - val_loss: 762.1163 - val_mse: 762.1163 - val_mae: 20.7938 - 121s/epoch - 110ms/st
ep

Epoch 19/100

1099/1099 - 122s - loss: 762.9670 - mse: 762.9670 - mae: 20.9315 - val_loss: 769.5239 - val_mse: 769.5239 - val_mae: 21.1745 - 122s/epoch - 111ms/st
ep

Epoch 20/100

1099/1099 - 121s - loss: 756.5504 - mse: 756.5504 - mae: 20.7920 - val_loss: 751.6793 - val_mse: 751.6793 - val_mae: 20.6618 - 121s/epoch - 110ms/st
ep

Epoch 21/100

1099/1099 - 121s - loss: 749.5264 - mse: 749.5264 - mae: 20.6585 - val_loss: 749.2751 - val_mse: 749.2751 - val_mae: 20.6283 - 121s/epoch - 110ms/st
ep

Epoch 22/100

1099/1099 - 121s - loss: 742.0618 - mse: 742.0618 - mae: 20.5091 - val_loss: 737.7689 - val_mse: 737.7689 - val_mae: 20.3217 - 121s/epoch - 110ms/st
ep

Epoch 23/100

1099/1099 - 122s - loss: 734.8785 - mse: 734.8785 - mae: 20.3854 - val_loss: 738.0788 - val_mse: 738.0788 - val_mae: 20.3814 - 122s/epoch - 111ms/st
ep

Epoch 24/100

1099/1099 - 122s - loss: 729.8777 - mse: 729.8777 - mae: 20.2637 - val_loss: 735.2083 - val_mse: 735.2083 - val_mae: 20.3310 - 122s/epoch - 111ms/st
ep

Epoch 25/100

1099/1099 - 122s - loss: 724.8394 - mse: 724.8394 - mae: 20.1535 - val_loss: 725.9302 - val_mse: 725.9302 - val_mae: 20.1165 - 122s/epoch - 111ms/st
ep

Epoch 26/100

1099/1099 - 121s - loss: 715.6844 - mse: 715.6844 - mae: 19.9910 - val_loss: 722.1128 - val_mse: 722.1128 - val_mae: 20.0095 - 121s/epoch - 110ms/st
ep

Epoch 27/100

1099/1099 - 121s - loss: 711.1405 - mse: 711.1405 - mae: 19.8682 - val_loss: 716.4858 - val_mse: 716.4858 - val_mae: 19.8730 - 121s/epoch - 110ms/st
ep

Epoch 28/100

1099/1099 - 121s - loss: 704.0187 - mse: 704.0187 - mae: 19.7366 - val_loss: 708.4234 - val_mse: 708.4234 - val_mae: 19.6742 - 121s/epoch - 110ms/st
ep

Epoch 29/100

1099/1099 - 122s - loss: 699.8266 - mse: 699.8266 - mae: 19.6587 - val_loss: 708.0591 - val_mse: 708.0591 - val_mae: 19.7538 - 122s/epoch - 111ms/st
ep

Epoch 30/100

1099/1099 - 122s - loss: 686.9718 - mse: 686.9718 - mae: 19.4090 - val_loss: 699.0013 - val_mse: 699.0013 - val_mae: 19.6089 - 122s/epoch - 111ms/st
ep

Epoch 31/100

1099/1099 - 121s - loss: 680.9982 - mse: 680.9982 - mae: 19.2841 - val_loss: 688.3813 - val_mse: 688.3813 - val_mae: 19.2088 - 121s/epoch - 110ms/step
Epoch 32/100
1099/1099 - 121s - loss: 672.8629 - mse: 672.8629 - mae: 19.1187 - val_loss: 686.9972 - val_mse: 686.9972 - val_mae: 19.2455 - 121s/epoch - 110ms/step
Epoch 33/100
1099/1099 - 121s - loss: 667.9332 - mse: 667.9332 - mae: 19.0181 - val_loss: 684.6542 - val_mse: 684.6542 - val_mae: 19.2532 - 121s/epoch - 110ms/step
Epoch 34/100
1099/1099 - 122s - loss: 661.8458 - mse: 661.8458 - mae: 18.8950 - val_loss: 680.7401 - val_mse: 680.7401 - val_mae: 19.1619 - 122s/epoch - 111ms/step
Epoch 35/100
1099/1099 - 121s - loss: 657.2310 - mse: 657.2310 - mae: 18.8123 - val_loss: 677.2433 - val_mse: 677.2433 - val_mae: 19.1148 - 121s/epoch - 110ms/step
Epoch 36/100
1099/1099 - 121s - loss: 649.3768 - mse: 649.3768 - mae: 18.6516 - val_loss: 666.0004 - val_mse: 666.0004 - val_mae: 18.8584 - 121s/epoch - 110ms/step
Epoch 37/100
1099/1099 - 121s - loss: 648.7452 - mse: 648.7452 - mae: 18.6271 - val_loss: 674.8153 - val_mse: 674.8153 - val_mae: 19.1966 - 121s/epoch - 110ms/step
Epoch 38/100
1099/1099 - 121s - loss: 640.9825 - mse: 640.9825 - mae: 18.4969 - val_loss: 658.1334 - val_mse: 658.1334 - val_mae: 18.6170 - 121s/epoch - 110ms/step
Epoch 39/100
1099/1099 - 121s - loss: 633.1066 - mse: 633.1066 - mae: 18.3444 - val_loss: 658.5206 - val_mse: 658.5206 - val_mae: 18.7112 - 121s/epoch - 110ms/step
Epoch 40/100
1099/1099 - 122s - loss: 631.8412 - mse: 631.8412 - mae: 18.2974 - val_loss: 659.5479 - val_mse: 659.5479 - val_mae: 18.7993 - 122s/epoch - 111ms/step
Epoch 41/100
1099/1099 - 122s - loss: 625.6940 - mse: 625.6940 - mae: 18.1844 - val_loss: 653.7411 - val_mse: 653.7411 - val_mae: 18.6295 - 122s/epoch - 111ms/step
Epoch 42/100
1099/1099 - 122s - loss: 620.2148 - mse: 620.2148 - mae: 18.0751 - val_loss: 649.9553 - val_mse: 649.9553 - val_mae: 18.5688 - 122s/epoch - 111ms/step
Epoch 43/100
1099/1099 - 122s - loss: 617.1749 - mse: 617.1749 - mae: 18.0130 - val_loss: 645.7285 - val_mse: 645.7285 - val_mae: 18.4121 - 122s/epoch - 111ms/step
Epoch 44/100
1099/1099 - 121s - loss: 612.3329 - mse: 612.3329 - mae: 17.9054 - val_loss: 655.6520 - val_mse: 655.6520 - val_mae: 18.6384 - 121s/epoch - 110ms/step
Epoch 45/100
1099/1099 - 121s - loss: 607.7928 - mse: 607.7928 - mae: 17.8338 - val_loss: 646.2257 - val_mse: 646.2257 - val_mae: 18.5417 - 121s/epoch - 110ms/step
Epoch 46/100
1099/1099 - 121s - loss: 603.7157 - mse: 603.7157 - mae: 17.7322 - val_loss:

s: 640.2560 - val_mse: 640.2560 - val_mae: 18.3809 - 121s/epoch - 110ms/st
ep
Epoch 47/100
1099/1099 - 121s - loss: 600.2142 - mse: 600.2142 - mae: 17.6627 - val_los
s: 641.7457 - val_mse: 641.7457 - val_mae: 18.3901 - 121s/epoch - 110ms/st
ep
Epoch 48/100
1099/1099 - 121s - loss: 597.5131 - mse: 597.5131 - mae: 17.5989 - val_los
s: 628.4609 - val_mse: 628.4609 - val_mae: 18.0033 - 121s/epoch - 110ms/st
ep
Epoch 49/100
1099/1099 - 121s - loss: 595.0883 - mse: 595.0883 - mae: 17.5353 - val_los
s: 640.0764 - val_mse: 640.0764 - val_mae: 18.2441 - 121s/epoch - 110ms/st
ep
Epoch 50/100
1099/1099 - 121s - loss: 590.9971 - mse: 590.9971 - mae: 17.4906 - val_los
s: 624.3300 - val_mse: 624.3300 - val_mae: 17.8844 - 121s/epoch - 110ms/st
ep
Epoch 51/100
1099/1099 - 121s - loss: 586.5233 - mse: 586.5233 - mae: 17.3946 - val_los
s: 653.5497 - val_mse: 653.5497 - val_mae: 18.7292 - 121s/epoch - 110ms/st
ep
Epoch 52/100
1099/1099 - 121s - loss: 585.9349 - mse: 585.9349 - mae: 17.3679 - val_los
s: 628.2252 - val_mse: 628.2252 - val_mae: 18.0246 - 121s/epoch - 110ms/st
ep
Epoch 53/100
1099/1099 - 121s - loss: 580.9141 - mse: 580.9141 - mae: 17.2732 - val_los
s: 633.3488 - val_mse: 633.3488 - val_mae: 18.2113 - 121s/epoch - 110ms/st
ep
Epoch 54/100
1099/1099 - 121s - loss: 574.4342 - mse: 574.4342 - mae: 17.1683 - val_los
s: 617.6712 - val_mse: 617.6712 - val_mae: 17.8016 - 121s/epoch - 110ms/st
ep
Epoch 55/100
1099/1099 - 122s - loss: 573.2401 - mse: 573.2401 - mae: 17.1323 - val_los
s: 631.8395 - val_mse: 631.8395 - val_mae: 18.2973 - 122s/epoch - 111ms/st
ep
Epoch 56/100
1099/1099 - 121s - loss: 571.5531 - mse: 571.5531 - mae: 17.0849 - val_los
s: 616.7543 - val_mse: 616.7543 - val_mae: 17.8544 - 121s/epoch - 110ms/st
ep
Epoch 57/100
1099/1099 - 121s - loss: 566.0838 - mse: 566.0838 - mae: 17.0144 - val_los
s: 614.1036 - val_mse: 614.1036 - val_mae: 17.7729 - 121s/epoch - 111ms/st
ep
Epoch 58/100
1099/1099 - 123s - loss: 563.6394 - mse: 563.6394 - mae: 16.9545 - val_los
s: 626.4923 - val_mse: 626.4923 - val_mae: 18.1013 - 123s/epoch - 112ms/st
ep
Epoch 59/100
1099/1099 - 122s - loss: 561.5654 - mse: 561.5654 - mae: 16.9007 - val_los
s: 617.6746 - val_mse: 617.6746 - val_mae: 17.8576 - 122s/epoch - 111ms/st
ep
Epoch 60/100
1099/1099 - 122s - loss: 555.6356 - mse: 555.6356 - mae: 16.8028 - val_los
s: 613.5953 - val_mse: 613.5953 - val_mae: 17.6379 - 122s/epoch - 111ms/st
ep
Epoch 61/100
1099/1099 - 122s - loss: 550.8956 - mse: 550.8956 - mae: 16.7369 - val_los
s: 608.9308 - val_mse: 608.9308 - val_mae: 17.6155 - 122s/epoch - 111ms/st

ep
Epoch 62/100
1099/1099 - 122s - loss: 548.1346 - mse: 548.1346 - mae: 16.6625 - val_loss: 622.7263 - val_mse: 622.7263 - val_mae: 17.8070 - 122s/epoch - 111ms/st
ep
Epoch 63/100
1099/1099 - 122s - loss: 547.2802 - mse: 547.2802 - mae: 16.6344 - val_loss: 603.6377 - val_mse: 603.6377 - val_mae: 17.5601 - 122s/epoch - 111ms/st
ep
Epoch 64/100
1099/1099 - 121s - loss: 542.8777 - mse: 542.8777 - mae: 16.5812 - val_loss: 606.0582 - val_mse: 606.0582 - val_mae: 17.6826 - 121s/epoch - 110ms/st
ep
Epoch 65/100
1099/1099 - 122s - loss: 542.0021 - mse: 542.0021 - mae: 16.5169 - val_loss: 605.0950 - val_mse: 605.0950 - val_mae: 17.6095 - 122s/epoch - 111ms/st
ep
Epoch 66/100
1099/1099 - 122s - loss: 535.1974 - mse: 535.1974 - mae: 16.4282 - val_loss: 605.7291 - val_mse: 605.7291 - val_mae: 17.6318 - 122s/epoch - 111ms/st
ep
Epoch 67/100
1099/1099 - 122s - loss: 530.2233 - mse: 530.2233 - mae: 16.3167 - val_loss: 613.4329 - val_mse: 613.4329 - val_mae: 17.5631 - 122s/epoch - 111ms/st
ep
Epoch 68/100
1099/1099 - 122s - loss: 528.3396 - mse: 528.3396 - mae: 16.2701 - val_loss: 593.2491 - val_mse: 593.2491 - val_mae: 17.3052 - 122s/epoch - 111ms/st
ep
Epoch 69/100
1099/1099 - 122s - loss: 526.9913 - mse: 526.9913 - mae: 16.2612 - val_loss: 610.8624 - val_mse: 610.8624 - val_mae: 17.8334 - 122s/epoch - 111ms/st
ep
Epoch 70/100
1099/1099 - 122s - loss: 523.3195 - mse: 523.3195 - mae: 16.1718 - val_loss: 618.7324 - val_mse: 618.7324 - val_mae: 17.9462 - 122s/epoch - 111ms/st
ep
Epoch 71/100
1099/1099 - 122s - loss: 522.5530 - mse: 522.5530 - mae: 16.1413 - val_loss: 596.7200 - val_mse: 596.7200 - val_mae: 17.3458 - 122s/epoch - 111ms/st
ep
Epoch 72/100
1099/1099 - 122s - loss: 519.4672 - mse: 519.4672 - mae: 16.0874 - val_loss: 607.6735 - val_mse: 607.6735 - val_mae: 17.6976 - 122s/epoch - 111ms/st
ep
Epoch 73/100
1099/1099 - 122s - loss: 514.8099 - mse: 514.8099 - mae: 16.0098 - val_loss: 597.7845 - val_mse: 597.7845 - val_mae: 17.3357 - 122s/epoch - 111ms/st
ep
Epoch 74/100
1099/1099 - 123s - loss: 514.2049 - mse: 514.2049 - mae: 15.9921 - val_loss: 591.3371 - val_mse: 591.3371 - val_mae: 17.2924 - 123s/epoch - 112ms/st
ep
Epoch 75/100
1099/1099 - 122s - loss: 507.8681 - mse: 507.8681 - mae: 15.8505 - val_loss: 579.5782 - val_mse: 579.5782 - val_mae: 17.0090 - 122s/epoch - 111ms/st
ep
Epoch 76/100
1099/1099 - 122s - loss: 504.8878 - mse: 504.8878 - mae: 15.8264 - val_loss: 586.2807 - val_mse: 586.2807 - val_mae: 17.3018 - 122s/epoch - 111ms/st
ep

Epoch 77/100

1099/1099 - 123s - loss: 503.7386 - mse: 503.7386 - mae: 15.7930 - val_loss: 579.8618 - val_mse: 579.8618 - val_mae: 17.0173 - 123s/epoch - 112ms/step

Epoch 78/100

1099/1099 - 123s - loss: 499.5308 - mse: 499.5308 - mae: 15.7014 - val_loss: 575.7191 - val_mse: 575.7191 - val_mae: 17.0380 - 123s/epoch - 112ms/step

Epoch 79/100

1099/1099 - 122s - loss: 497.5346 - mse: 497.5346 - mae: 15.6579 - val_loss: 574.1452 - val_mse: 574.1452 - val_mae: 16.9503 - 122s/epoch - 111ms/step

Epoch 80/100

1099/1099 - 127s - loss: 497.2852 - mse: 497.2852 - mae: 15.6261 - val_loss: 585.7650 - val_mse: 585.7650 - val_mae: 17.2284 - 127s/epoch - 115ms/step

Epoch 81/100

1099/1099 - 124s - loss: 492.7578 - mse: 492.7578 - mae: 15.5717 - val_loss: 576.2000 - val_mse: 576.2000 - val_mae: 16.9693 - 124s/epoch - 113ms/step

Epoch 82/100

1099/1099 - 122s - loss: 488.1373 - mse: 488.1373 - mae: 15.4511 - val_loss: 569.6962 - val_mse: 569.6962 - val_mae: 16.8125 - 122s/epoch - 111ms/step

Epoch 83/100

1099/1099 - 123s - loss: 484.6519 - mse: 484.6519 - mae: 15.4100 - val_loss: 558.9392 - val_mse: 558.9392 - val_mae: 16.5746 - 123s/epoch - 112ms/step

Epoch 84/100

1099/1099 - 121s - loss: 482.0196 - mse: 482.0196 - mae: 15.3273 - val_loss: 567.9360 - val_mse: 567.9360 - val_mae: 16.8154 - 121s/epoch - 111ms/step

Epoch 85/100

1099/1099 - 122s - loss: 476.5275 - mse: 476.5275 - mae: 15.2442 - val_loss: 565.0546 - val_mse: 565.0546 - val_mae: 16.7830 - 122s/epoch - 111ms/step

Epoch 86/100

1099/1099 - 122s - loss: 471.9028 - mse: 471.9028 - mae: 15.1646 - val_loss: 564.2339 - val_mse: 564.2339 - val_mae: 16.6206 - 122s/epoch - 111ms/step

Epoch 87/100

1099/1099 - 121s - loss: 468.1417 - mse: 468.1417 - mae: 15.0976 - val_loss: 547.9575 - val_mse: 547.9575 - val_mae: 16.5050 - 121s/epoch - 110ms/step

Epoch 88/100

1099/1099 - 121s - loss: 465.9435 - mse: 465.9435 - mae: 15.0067 - val_loss: 547.6498 - val_mse: 547.6498 - val_mae: 16.2576 - 121s/epoch - 110ms/step

Epoch 89/100

1099/1099 - 122s - loss: 461.0446 - mse: 461.0446 - mae: 14.9261 - val_loss: 556.9908 - val_mse: 556.9908 - val_mae: 16.5421 - 122s/epoch - 111ms/step

Epoch 90/100

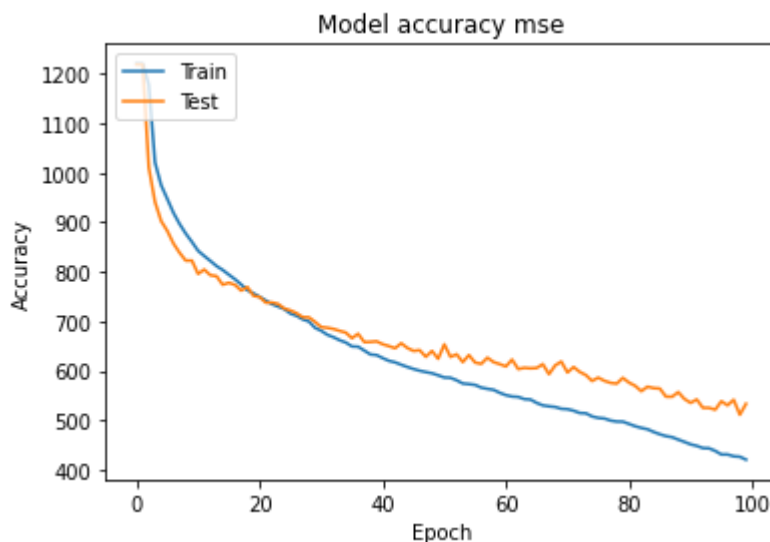
1099/1099 - 121s - loss: 456.4438 - mse: 456.4438 - mae: 14.8531 - val_loss: 543.2483 - val_mse: 543.2483 - val_mae: 16.2131 - 121s/epoch - 110ms/step

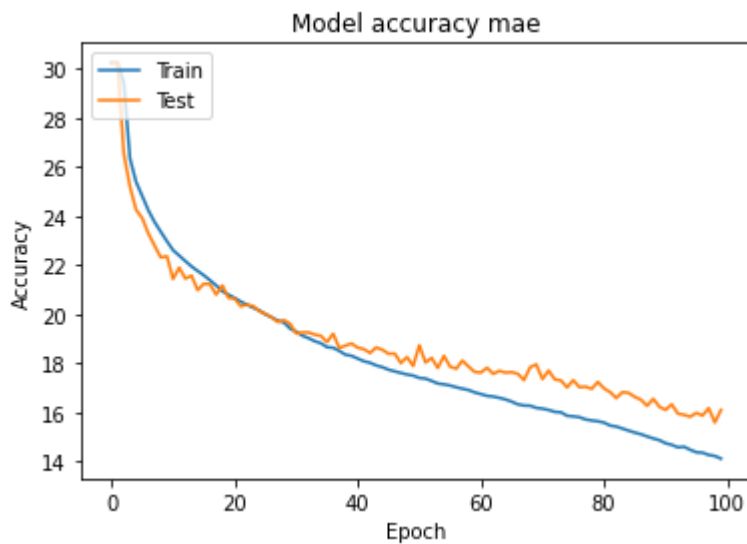
Epoch 91/100

1099/1099 - 121s - loss: 451.4556 - mse: 451.4556 - mae: 14.7294 - val_loss: 535.2781 - val_mse: 535.2781 - val_mae: 16.0903 - 121s/epoch - 110ms/step

Epoch 92/100

1099/1099 - 124s - loss: 448.4187 - mse: 448.4187 - mae: 14.6648 - val_loss: 542.1154 - val_mse: 542.1154 - val_mae: 16.3163 - 124s/epoch - 113ms/step
 Epoch 93/100
 1099/1099 - 121s - loss: 443.9200 - mse: 443.9200 - mae: 14.5633 - val_loss: 525.2914 - val_mse: 525.2914 - val_mae: 15.9391 - 121s/epoch - 110ms/step
 Epoch 94/100
 1099/1099 - 121s - loss: 443.4789 - mse: 443.4789 - mae: 14.5848 - val_loss: 525.1678 - val_mse: 525.1678 - val_mae: 15.8893 - 121s/epoch - 110ms/step
 Epoch 95/100
 1099/1099 - 122s - loss: 438.2408 - mse: 438.2408 - mae: 14.4632 - val_loss: 521.5791 - val_mse: 521.5791 - val_mae: 15.8110 - 122s/epoch - 111ms/step
 Epoch 96/100
 1099/1099 - 121s - loss: 431.0370 - mse: 431.0370 - mae: 14.3596 - val_loss: 538.4924 - val_mse: 538.4924 - val_mae: 15.9671 - 121s/epoch - 110ms/step
 Epoch 97/100
 1099/1099 - 122s - loss: 430.9967 - mse: 430.9967 - mae: 14.3438 - val_loss: 530.3422 - val_mse: 530.3422 - val_mae: 15.8602 - 122s/epoch - 111ms/step
 Epoch 98/100
 1099/1099 - 121s - loss: 427.3611 - mse: 427.3611 - mae: 14.2505 - val_loss: 541.4880 - val_mse: 541.4880 - val_mae: 16.1644 - 121s/epoch - 110ms/step
 Epoch 99/100
 1099/1099 - 121s - loss: 426.4020 - mse: 426.4020 - mae: 14.2106 - val_loss: 511.3421 - val_mse: 511.3421 - val_mae: 15.5762 - 121s/epoch - 110ms/step
 Epoch 100/100
 1099/1099 - 121s - loss: 420.5662 - mse: 420.5662 - mae: 14.1008 - val_loss: 533.2664 - val_mse: 533.2664 - val_mae: 16.0922 - 121s/epoch - 110ms/step





MUSIC MSE: 1375.568

MUSIC MAE: 21.1539

Out of range MUSIC prediction: 0

In []:

```
magnitude = pd.read_csv('/content/drive/MyDrive/train_magnitude.csv', header=None).to_numpy()
output_data = pd.read_csv('/content/drive/MyDrive/train_outputs.csv', header=None).to_numpy()
phase = pd.read_csv('/content/drive/MyDrive/train_phase.csv', header=None).to_numpy()

data = load_data_cnn(phase, magnitude, output_data, antenna_num)
phase_data = data[0]
magnitude_data = data[1]
output_data = data[2]

data_split = split_test_train(phase_data, magnitude_data, output_data, 0.4)
x_train_magnitude = data_split[0]
x_test_magnitude = data_split[1]
x_train_phase = data_split[2]
x_test_phase = data_split[3]
y_train = data_split[4][:,0:2]
y_test = data_split[5][:,0:2]
```

In []:

```
antenna_num = 2
filters=(64,32,16)
lr = 0.001
epochs = 100
opt = Adam(learning_rate=lr)
regress=False

phase = create_2d_cnn(100, 4, 1, filters, regress, "relu")
magnitude = create_2d_cnn(100, 4, 1, filters, regress, "relu")

model = combine_models(phase, magnitude, (10,))
model.compile(loss='mean_squared_error', optimizer=opt, metrics=['mse', 'mae'])

history = model.fit(
x=[x_train_magnitude, x_train_phase], y=y_train,
  validation_data=(x_test_magnitude, x_test_phase), y_test),
  epochs=epochs, batch_size=64, verbose=2
)

display_graphs(history)

comparison = MUSIC_metrics(data_split[5])
print("MUSIC MSE: ", comparison[1])
print("MUSIC MAE: ", comparison[0])
print("Out of range MUSIC prediction: ", len(comparison[2]))

index = comparison[2][0]

print("Music example preiction for MUSIC nan")
print("Actual: [", data_split[5][index][0], " ", data_split[5][index][1], "]" )
predictions = model.predict([x_test_magnitude, x_test_phase])
print("Prediction: ", predictions[index])
```

Epoch 1/100

1099/1099 - 164s - loss: 920.7108 - mse: 920.7108 - mae: 23.8552 - val_loss: 801.9182 - val_mse: 801.9182 - val_mae: 20.7510 - 164s/epoch - 149ms/step

Epoch 2/100

1099/1099 - 161s - loss: 807.4346 - mse: 807.4346 - mae: 21.2674 - val_loss: 767.1603 - val_mse: 767.1603 - val_mae: 20.5348 - 161s/epoch - 147ms/step

Epoch 3/100

1099/1099 - 164s - loss: 779.0401 - mse: 779.0401 - mae: 20.6472 - val_loss: 744.7557 - val_mse: 744.7557 - val_mae: 19.2824 - 164s/epoch - 149ms/step

Epoch 4/100

1099/1099 - 163s - loss: 765.5746 - mse: 765.5746 - mae: 20.2909 - val_loss: 742.4951 - val_mse: 742.4951 - val_mae: 19.7193 - 163s/epoch - 149ms/step

Epoch 5/100

1099/1099 - 163s - loss: 752.1844 - mse: 752.1844 - mae: 19.9550 - val_loss: 703.4613 - val_mse: 703.4613 - val_mae: 18.6921 - 163s/epoch - 148ms/step

Epoch 6/100

1099/1099 - 161s - loss: 733.3254 - mse: 733.3254 - mae: 19.5963 - val_loss: 702.7101 - val_mse: 702.7101 - val_mae: 18.1432 - 161s/epoch - 147ms/step

Epoch 7/100

1099/1099 - 163s - loss: 706.0722 - mse: 706.0722 - mae: 19.0691 - val_loss: 616.2882 - val_mse: 616.2882 - val_mae: 16.6075 - 163s/epoch - 148ms/step

Epoch 8/100

1099/1099 - 162s - loss: 668.6118 - mse: 668.6118 - mae: 18.2904 - val_loss: 625.1597 - val_mse: 625.1597 - val_mae: 18.2909 - 162s/epoch - 148ms/step

Epoch 9/100

1099/1099 - 163s - loss: 639.4239 - mse: 639.4239 - mae: 17.6867 - val_loss: 589.1785 - val_mse: 589.1785 - val_mae: 16.8018 - 163s/epoch - 149ms/step

Epoch 10/100

1099/1099 - 164s - loss: 615.5593 - mse: 615.5593 - mae: 17.1944 - val_loss: 556.8749 - val_mse: 556.8749 - val_mae: 15.3737 - 164s/epoch - 149ms/step

Epoch 11/100

1099/1099 - 164s - loss: 593.8275 - mse: 593.8275 - mae: 16.7709 - val_loss: 535.6553 - val_mse: 535.6553 - val_mae: 15.0668 - 164s/epoch - 149ms/step

Epoch 12/100

1099/1099 - 165s - loss: 579.2672 - mse: 579.2672 - mae: 16.4181 - val_loss: 553.1277 - val_mse: 553.1277 - val_mae: 15.7012 - 165s/epoch - 150ms/step

Epoch 13/100

1099/1099 - 164s - loss: 563.6663 - mse: 563.6663 - mae: 16.0879 - val_loss: 440.3730 - val_mse: 440.3730 - val_mae: 12.6585 - 164s/epoch - 149ms/step

Epoch 14/100

1099/1099 - 163s - loss: 547.3789 - mse: 547.3789 - mae: 15.8239 - val_loss: 416.5207 - val_mse: 416.5207 - val_mae: 12.2695 - 163s/epoch - 148ms/step

Epoch 15/100

1099/1099 - 162s - loss: 530.1920 - mse: 530.1920 - mae: 15.4074 - val_loss: 406.0198 - val_mse: 406.0198 - val_mae: 12.1891 - 162s/epoch - 148ms/step

Epoch 16/100

1099/1099 - 163s - loss: 512.9755 - mse: 512.9755 - mae: 14.9986 - val_loss: 391.6367 - val_mse: 391.6367 - val_mae: 12.0705 - 163s/epoch - 148ms/step
Epoch 17/100
1099/1099 - 163s - loss: 502.7098 - mse: 502.7098 - mae: 14.7528 - val_loss: 424.7804 - val_mse: 424.7804 - val_mae: 12.9531 - 163s/epoch - 149ms/step
Epoch 18/100
1099/1099 - 164s - loss: 490.7014 - mse: 490.7014 - mae: 14.5407 - val_loss: 352.8169 - val_mse: 352.8169 - val_mae: 10.8312 - 164s/epoch - 149ms/step
Epoch 19/100
1099/1099 - 164s - loss: 476.6518 - mse: 476.6518 - mae: 14.1988 - val_loss: 389.0634 - val_mse: 389.0634 - val_mae: 11.8584 - 164s/epoch - 149ms/step
Epoch 20/100
1099/1099 - 163s - loss: 466.1253 - mse: 466.1253 - mae: 13.9437 - val_loss: 349.4915 - val_mse: 349.4915 - val_mae: 11.3449 - 163s/epoch - 149ms/step
Epoch 21/100
1099/1099 - 164s - loss: 458.4405 - mse: 458.4405 - mae: 13.8121 - val_loss: 397.5102 - val_mse: 397.5102 - val_mae: 12.4963 - 164s/epoch - 149ms/step
Epoch 22/100
1099/1099 - 163s - loss: 450.7635 - mse: 450.7635 - mae: 13.6161 - val_loss: 353.1011 - val_mse: 353.1011 - val_mae: 11.1148 - 163s/epoch - 149ms/step
Epoch 23/100
1099/1099 - 163s - loss: 442.4507 - mse: 442.4507 - mae: 13.4679 - val_loss: 351.2157 - val_mse: 351.2157 - val_mae: 10.7698 - 163s/epoch - 148ms/step
Epoch 24/100
1099/1099 - 162s - loss: 438.6650 - mse: 438.6650 - mae: 13.3779 - val_loss: 414.9632 - val_mse: 414.9632 - val_mae: 12.0963 - 162s/epoch - 148ms/step
Epoch 25/100
1099/1099 - 164s - loss: 431.5531 - mse: 431.5531 - mae: 13.2395 - val_loss: 331.5049 - val_mse: 331.5049 - val_mae: 10.6789 - 164s/epoch - 149ms/step
Epoch 26/100
1099/1099 - 162s - loss: 425.6254 - mse: 425.6254 - mae: 13.1148 - val_loss: 341.9999 - val_mse: 341.9999 - val_mae: 10.0349 - 162s/epoch - 148ms/step
Epoch 27/100
1099/1099 - 163s - loss: 417.8536 - mse: 417.8536 - mae: 12.9434 - val_loss: 356.4768 - val_mse: 356.4768 - val_mae: 10.0338 - 163s/epoch - 148ms/step
Epoch 28/100
1099/1099 - 164s - loss: 408.4824 - mse: 408.4824 - mae: 12.7573 - val_loss: 320.3737 - val_mse: 320.3737 - val_mae: 9.9307 - 164s/epoch - 149ms/step
Epoch 29/100
1099/1099 - 162s - loss: 410.2840 - mse: 410.2840 - mae: 12.7627 - val_loss: 298.0253 - val_mse: 298.0253 - val_mae: 9.7342 - 162s/epoch - 148ms/step
Epoch 30/100
1099/1099 - 162s - loss: 399.2497 - mse: 399.2497 - mae: 12.5633 - val_loss: 282.9524 - val_mse: 282.9524 - val_mae: 9.5399 - 162s/epoch - 148ms/step
Epoch 31/100
1099/1099 - 162s - loss: 395.7394 - mse: 395.7394 - mae: 12.4685 - val_loss:

s: 312.0878 - val_mse: 312.0878 - val_mae: 9.6146 - 162s/epoch - 147ms/step
Epoch 32/100
1099/1099 - 163s - loss: 394.1809 - mse: 394.1809 - mae: 12.4303 - val_loss: 313.2788 - val_mse: 313.2788 - val_mae: 10.3901 - 163s/epoch - 148ms/step
Epoch 33/100
1099/1099 - 163s - loss: 388.3496 - mse: 388.3496 - mae: 12.3050 - val_loss: 296.3410 - val_mse: 296.3410 - val_mae: 9.8605 - 163s/epoch - 148ms/step
Epoch 34/100
1099/1099 - 164s - loss: 388.7788 - mse: 388.7788 - mae: 12.2623 - val_loss: 383.7821 - val_mse: 383.7821 - val_mae: 10.9166 - 164s/epoch - 149ms/step
Epoch 35/100
1099/1099 - 162s - loss: 382.9593 - mse: 382.9593 - mae: 12.1445 - val_loss: 292.2452 - val_mse: 292.2452 - val_mae: 9.0680 - 162s/epoch - 147ms/step
Epoch 36/100
1099/1099 - 162s - loss: 378.6884 - mse: 378.6884 - mae: 12.0181 - val_loss: 299.6748 - val_mse: 299.6748 - val_mae: 9.5269 - 162s/epoch - 148ms/step
Epoch 37/100
1099/1099 - 163s - loss: 375.3960 - mse: 375.3960 - mae: 11.9641 - val_loss: 272.0657 - val_mse: 272.0657 - val_mae: 9.6096 - 163s/epoch - 148ms/step
Epoch 38/100
1099/1099 - 163s - loss: 373.4230 - mse: 373.4230 - mae: 11.9018 - val_loss: 265.1270 - val_mse: 265.1270 - val_mae: 8.9132 - 163s/epoch - 148ms/step
Epoch 39/100
1099/1099 - 164s - loss: 368.5201 - mse: 368.5201 - mae: 11.8158 - val_loss: 265.0399 - val_mse: 265.0399 - val_mae: 8.5125 - 164s/epoch - 149ms/step
Epoch 40/100
1099/1099 - 164s - loss: 366.8125 - mse: 366.8125 - mae: 11.7695 - val_loss: 263.2526 - val_mse: 263.2526 - val_mae: 8.9788 - 164s/epoch - 149ms/step
Epoch 41/100
1099/1099 - 163s - loss: 361.7670 - mse: 361.7670 - mae: 11.6521 - val_loss: 252.5164 - val_mse: 252.5164 - val_mae: 8.7756 - 163s/epoch - 148ms/step
Epoch 42/100
1099/1099 - 162s - loss: 357.0591 - mse: 357.0591 - mae: 11.5619 - val_loss: 283.5135 - val_mse: 283.5135 - val_mae: 9.5355 - 162s/epoch - 148ms/step
Epoch 43/100
1099/1099 - 163s - loss: 354.8132 - mse: 354.8132 - mae: 11.5199 - val_loss: 308.8343 - val_mse: 308.8343 - val_mae: 9.5698 - 163s/epoch - 149ms/step
Epoch 44/100
1099/1099 - 163s - loss: 354.6314 - mse: 354.6314 - mae: 11.4642 - val_loss: 273.9554 - val_mse: 273.9554 - val_mae: 8.5353 - 163s/epoch - 148ms/step
Epoch 45/100
1099/1099 - 162s - loss: 354.6002 - mse: 354.6002 - mae: 11.4590 - val_loss: 276.5737 - val_mse: 276.5737 - val_mae: 8.5838 - 162s/epoch - 148ms/step
Epoch 46/100
1099/1099 - 163s - loss: 352.7380 - mse: 352.7380 - mae: 11.4166 - val_loss: 215.4649 - val_mse: 215.4649 - val_mae: 7.7511 - 163s/epoch - 148ms/step

p
Epoch 47/100
1099/1099 - 163s - loss: 346.7590 - mse: 346.7590 - mae: 11.3027 - val_loss: 244.5855 - val_mse: 244.5855 - val_mae: 8.4640 - 163s/epoch - 148ms/step
p
Epoch 48/100
1099/1099 - 163s - loss: 342.8677 - mse: 342.8677 - mae: 11.2179 - val_loss: 283.7913 - val_mse: 283.7913 - val_mae: 8.2732 - 163s/epoch - 148ms/step
p
Epoch 49/100
1099/1099 - 163s - loss: 345.5799 - mse: 345.5799 - mae: 11.2659 - val_loss: 256.8016 - val_mse: 256.8016 - val_mae: 8.4296 - 163s/epoch - 148ms/step
p
Epoch 50/100
1099/1099 - 161s - loss: 343.4594 - mse: 343.4594 - mae: 11.1997 - val_loss: 230.7967 - val_mse: 230.7967 - val_mae: 8.2711 - 161s/epoch - 147ms/step
p
Epoch 51/100
1099/1099 - 163s - loss: 339.4018 - mse: 339.4018 - mae: 11.0891 - val_loss: 296.1174 - val_mse: 296.1174 - val_mae: 8.9256 - 163s/epoch - 148ms/step
p
Epoch 52/100
1099/1099 - 162s - loss: 341.2154 - mse: 341.2154 - mae: 11.1133 - val_loss: 226.6825 - val_mse: 226.6825 - val_mae: 7.9737 - 162s/epoch - 148ms/step
p
Epoch 53/100
1099/1099 - 162s - loss: 334.5053 - mse: 334.5053 - mae: 11.0198 - val_loss: 248.3322 - val_mse: 248.3322 - val_mae: 9.0878 - 162s/epoch - 148ms/step
p
Epoch 54/100
1099/1099 - 163s - loss: 334.5648 - mse: 334.5648 - mae: 11.0138 - val_loss: 241.2182 - val_mse: 241.2182 - val_mae: 7.7438 - 163s/epoch - 149ms/step
p
Epoch 55/100
1099/1099 - 161s - loss: 331.7254 - mse: 331.7254 - mae: 10.9583 - val_loss: 267.2649 - val_mse: 267.2649 - val_mae: 8.3187 - 161s/epoch - 147ms/step
p
Epoch 56/100
1099/1099 - 162s - loss: 331.3712 - mse: 331.3712 - mae: 10.9091 - val_loss: 227.7070 - val_mse: 227.7070 - val_mae: 7.6607 - 162s/epoch - 148ms/step
p
Epoch 57/100
1099/1099 - 162s - loss: 332.7068 - mse: 332.7068 - mae: 10.9037 - val_loss: 238.0725 - val_mse: 238.0725 - val_mae: 8.1838 - 162s/epoch - 148ms/step
p
Epoch 58/100
1099/1099 - 163s - loss: 327.7724 - mse: 327.7724 - mae: 10.8286 - val_loss: 291.9584 - val_mse: 291.9584 - val_mae: 8.5535 - 163s/epoch - 148ms/step
p
Epoch 59/100
1099/1099 - 163s - loss: 327.5980 - mse: 327.5980 - mae: 10.8307 - val_loss: 265.2464 - val_mse: 265.2464 - val_mae: 8.1621 - 163s/epoch - 148ms/step
p
Epoch 60/100
1099/1099 - 163s - loss: 326.4719 - mse: 326.4719 - mae: 10.8026 - val_loss: 245.2028 - val_mse: 245.2028 - val_mae: 7.8317 - 163s/epoch - 148ms/step
p
Epoch 61/100
1099/1099 - 163s - loss: 319.6705 - mse: 319.6705 - mae: 10.7143 - val_loss: 286.7401 - val_mse: 286.7401 - val_mae: 8.5970 - 163s/epoch - 149ms/step
p

Epoch 62/100

1099/1099 - 164s - loss: 321.9509 - mse: 321.9509 - mae: 10.7109 - val_loss: 227.0987 - val_mse: 227.0987 - val_mae: 7.9656 - 164s/epoch - 149ms/step

Epoch 63/100

1099/1099 - 163s - loss: 317.7670 - mse: 317.7670 - mae: 10.6475 - val_loss: 271.6366 - val_mse: 271.6366 - val_mae: 8.1127 - 163s/epoch - 148ms/step

Epoch 64/100

1099/1099 - 164s - loss: 326.8047 - mse: 326.8047 - mae: 10.7487 - val_loss: 263.0584 - val_mse: 263.0584 - val_mae: 8.2005 - 164s/epoch - 150ms/step

Epoch 65/100

1099/1099 - 163s - loss: 314.6723 - mse: 314.6723 - mae: 10.5953 - val_loss: 269.8747 - val_mse: 269.8747 - val_mae: 8.5359 - 163s/epoch - 148ms/step

Epoch 66/100

1099/1099 - 164s - loss: 320.4204 - mse: 320.4204 - mae: 10.6837 - val_loss: 205.7747 - val_mse: 205.7747 - val_mae: 7.6560 - 164s/epoch - 149ms/step

Epoch 67/100

1099/1099 - 163s - loss: 318.3994 - mse: 318.3994 - mae: 10.6079 - val_loss: 274.7663 - val_mse: 274.7663 - val_mae: 8.5036 - 163s/epoch - 149ms/step

Epoch 68/100

1099/1099 - 163s - loss: 317.4967 - mse: 317.4967 - mae: 10.6048 - val_loss: 238.2967 - val_mse: 238.2967 - val_mae: 8.4767 - 163s/epoch - 148ms/step

Epoch 69/100

1099/1099 - 163s - loss: 315.1361 - mse: 315.1361 - mae: 10.5624 - val_loss: 231.7694 - val_mse: 231.7694 - val_mae: 7.4939 - 163s/epoch - 148ms/step

Epoch 70/100

1099/1099 - 164s - loss: 315.8132 - mse: 315.8132 - mae: 10.6329 - val_loss: 238.2920 - val_mse: 238.2920 - val_mae: 7.9684 - 164s/epoch - 149ms/step

Epoch 71/100

1099/1099 - 162s - loss: 312.6020 - mse: 312.6020 - mae: 10.5107 - val_loss: 207.5775 - val_mse: 207.5775 - val_mae: 7.5054 - 162s/epoch - 147ms/step

Epoch 72/100

1099/1099 - 162s - loss: 311.7339 - mse: 311.7339 - mae: 10.4684 - val_loss: 205.9739 - val_mse: 205.9739 - val_mae: 7.8690 - 162s/epoch - 148ms/step

Epoch 73/100

1099/1099 - 161s - loss: 308.2644 - mse: 308.2644 - mae: 10.4213 - val_loss: 237.8414 - val_mse: 237.8414 - val_mae: 7.8692 - 161s/epoch - 147ms/step

Epoch 74/100

1099/1099 - 161s - loss: 311.3011 - mse: 311.3011 - mae: 10.4331 - val_loss: 259.9254 - val_mse: 259.9254 - val_mae: 7.9182 - 161s/epoch - 147ms/step

Epoch 75/100

1099/1099 - 163s - loss: 306.0712 - mse: 306.0712 - mae: 10.3706 - val_loss: 277.6824 - val_mse: 277.6824 - val_mae: 8.0656 - 163s/epoch - 148ms/step

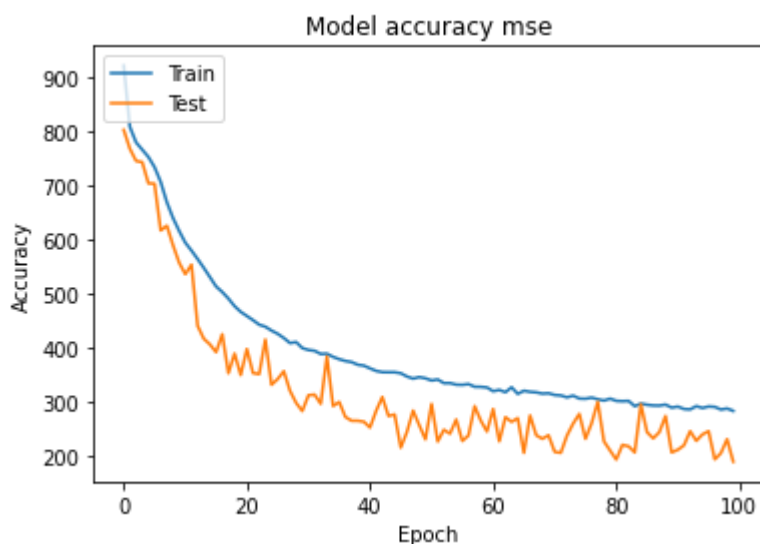
Epoch 76/100

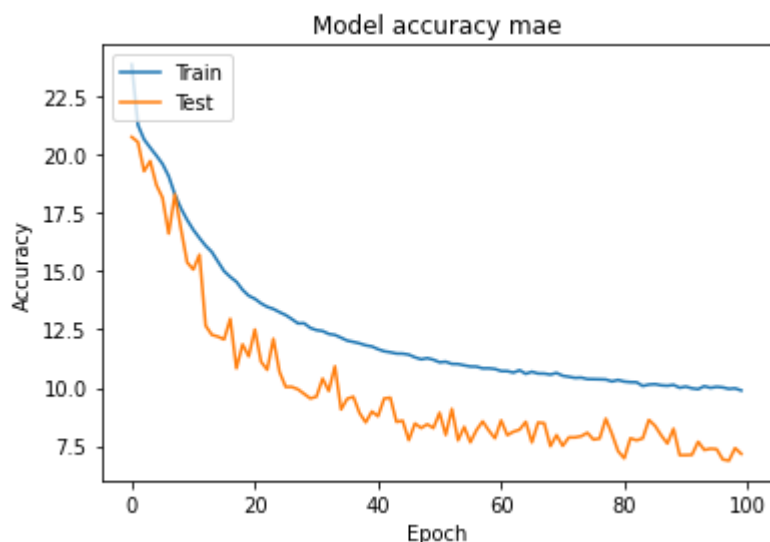
1099/1099 - 163s - loss: 305.7158 - mse: 305.7158 - mae: 10.3656 - val_loss: 231.8150 - val_mse: 231.8150 - val_mae: 7.7759 - 163s/epoch - 148ms/step

Epoch 77/100

1099/1099 - 162s - loss: 307.7103 - mse: 307.7103 - mae: 10.3595 - val_loss: 260.4654 - val_mse: 260.4654 - val_mae: 7.8218 - 162s/epoch - 148ms/step
Epoch 78/100
1099/1099 - 162s - loss: 304.6907 - mse: 304.6907 - mae: 10.3510 - val_loss: 300.0749 - val_mse: 300.0749 - val_mae: 8.6715 - 162s/epoch - 147ms/step
Epoch 79/100
1099/1099 - 161s - loss: 302.2947 - mse: 302.2947 - mae: 10.2701 - val_loss: 227.0569 - val_mse: 227.0569 - val_mae: 8.0193 - 161s/epoch - 147ms/step
Epoch 80/100
1099/1099 - 163s - loss: 305.8715 - mse: 305.8715 - mae: 10.3313 - val_loss: 210.0999 - val_mse: 210.0999 - val_mae: 7.2770 - 163s/epoch - 149ms/step
Epoch 81/100
1099/1099 - 162s - loss: 301.7531 - mse: 301.7531 - mae: 10.2625 - val_loss: 193.3916 - val_mse: 193.3916 - val_mae: 6.9705 - 162s/epoch - 148ms/step
Epoch 82/100
1099/1099 - 162s - loss: 301.1899 - mse: 301.1899 - mae: 10.2380 - val_loss: 220.5390 - val_mse: 220.5390 - val_mae: 7.8306 - 162s/epoch - 147ms/step
Epoch 83/100
1099/1099 - 163s - loss: 301.6656 - mse: 301.6656 - mae: 10.2339 - val_loss: 217.8443 - val_mse: 217.8443 - val_mae: 7.7447 - 163s/epoch - 148ms/step
Epoch 84/100
1099/1099 - 163s - loss: 292.0162 - mse: 292.0162 - mae: 10.0737 - val_loss: 206.6310 - val_mse: 206.6310 - val_mae: 7.8267 - 163s/epoch - 148ms/step
Epoch 85/100
1099/1099 - 162s - loss: 296.5973 - mse: 296.5973 - mae: 10.1344 - val_loss: 295.4116 - val_mse: 295.4116 - val_mae: 8.6190 - 162s/epoch - 148ms/step
Epoch 86/100
1099/1099 - 162s - loss: 294.5459 - mse: 294.5459 - mae: 10.1514 - val_loss: 243.9530 - val_mse: 243.9530 - val_mae: 8.3657 - 162s/epoch - 148ms/step
Epoch 87/100
1099/1099 - 163s - loss: 293.2633 - mse: 293.2633 - mae: 10.1024 - val_loss: 232.5864 - val_mse: 232.5864 - val_mae: 7.9549 - 163s/epoch - 148ms/step
Epoch 88/100
1099/1099 - 163s - loss: 293.0399 - mse: 293.0399 - mae: 10.0837 - val_loss: 243.9513 - val_mse: 243.9513 - val_mae: 7.6059 - 163s/epoch - 148ms/step
Epoch 89/100
1099/1099 - 163s - loss: 294.8976 - mse: 294.8976 - mae: 10.1217 - val_loss: 273.6815 - val_mse: 273.6815 - val_mae: 8.2397 - 163s/epoch - 148ms/step
Epoch 90/100
1099/1099 - 161s - loss: 289.2290 - mse: 289.2290 - mae: 9.9983 - val_loss: 206.5915 - val_mse: 206.5915 - val_mae: 7.1093 - 161s/epoch - 146ms/step
Epoch 91/100
1099/1099 - 163s - loss: 291.2237 - mse: 291.2237 - mae: 10.0473 - val_loss: 211.4569 - val_mse: 211.4569 - val_mae: 7.1098 - 163s/epoch - 148ms/step
Epoch 92/100
1099/1099 - 163s - loss: 286.7278 - mse: 286.7278 - mae: 9.9727 - val_loss:

s: 219.7345 - val_mse: 219.7345 - val_mae: 7.1217 - 163s/epoch - 148ms/step
 Epoch 93/100
 1099/1099 - 161s - loss: 286.0133 - mse: 286.0133 - mae: 9.9376 - val_loss: 245.8259 - val_mse: 245.8259 - val_mae: 7.6816 - 161s/epoch - 147ms/step
 Epoch 94/100
 1099/1099 - 162s - loss: 292.0183 - mse: 292.0183 - mae: 10.0647 - val_loss: 228.0164 - val_mse: 228.0164 - val_mae: 7.3312 - 162s/epoch - 148ms/step
 Epoch 95/100
 1099/1099 - 163s - loss: 288.5802 - mse: 288.5802 - mae: 9.9940 - val_loss: 239.7849 - val_mse: 239.7849 - val_mae: 7.3836 - 163s/epoch - 148ms/step
 Epoch 96/100
 1099/1099 - 163s - loss: 291.3874 - mse: 291.3874 - mae: 10.0370 - val_loss: 245.7693 - val_mse: 245.7693 - val_mae: 7.3653 - 163s/epoch - 148ms/step
 Epoch 97/100
 1099/1099 - 163s - loss: 290.6483 - mse: 290.6483 - mae: 10.0127 - val_loss: 193.7924 - val_mse: 193.7924 - val_mae: 6.9226 - 163s/epoch - 149ms/step
 Epoch 98/100
 1099/1099 - 163s - loss: 285.7290 - mse: 285.7290 - mae: 9.9496 - val_loss: 205.3830 - val_mse: 205.3830 - val_mae: 6.8717 - 163s/epoch - 148ms/step
 Epoch 99/100
 1099/1099 - 163s - loss: 287.6687 - mse: 287.6687 - mae: 9.9724 - val_loss: 231.0277 - val_mse: 231.0277 - val_mae: 7.4105 - 163s/epoch - 148ms/step
 Epoch 100/100
 1099/1099 - 163s - loss: 283.2629 - mse: 283.2629 - mae: 9.8807 - val_loss: 189.5630 - val_mse: 189.5630 - val_mae: 7.1643 - 163s/epoch - 148ms/step





MUSIC MSE: 75.57618

MUSIC MAE: 5.145462

Out of range MUSIC prediction: 211

Music example prediction for MUSIC nan

Actual: [-55.0 23.0]

Prediction: [-23.984808 29.892437]

In []:

```
comparison = MUSIC_metrics(data_split[5])
out_of_music_range = []
out_of_range_prediction = []
index = comparison[2][0]
comparison = MUSIC_metrics(data_split[5])

print("Out of range MUSIC prediction: ", len(comparison[2]))
predictions = model.predict([x_test_magnitude, x_test_phase])

for index in comparison[2]:
    out_of_music_range.append(data_split[5][index][0:2])
    out_of_range_prediction.append(predictions[index])

print("MAE predicted MUSIC nan: ", mean_absolute_error(out_of_music_range, out_of_range_prediction))
print("MAE predicted MUSIC nan: ", mean_squared_error(out_of_music_range, out_of_range_prediction))
```

Out of range MUSIC prediction: 211

MAE predicted MUSIC nan: 12.45418

MAE predicted MUSIC nan: 407.9396

Unit tests

Test load data method returns the expected data shape

In [16]:

```
from random import randint
mock_data = []
mock_output = [[1,1,1,1],[2,2,2,2],[3,3,3,3],[4,4,4,4]]

for i in range(400):
    mock_data.append([])
    for j in range(4):
        mock_data[i].append(randint(0,4))

x = load_data(np.asarray(mock_data), np.asarray(mock_data), mock_output, 2)
assert x[0].shape == (4, 400)
assert x[1].shape == (4, 400)
assert x[2].shape == (4, 4)
assert len(x) == 3

mock_data = []
mock_output = [[1,1,1,1],[2,2,2,2],[3,3,3,3],[4,4,4,4], [5,5,5,5]]

for i in range(500):
    mock_data.append([])
    for j in range(64):
        mock_data[i].append(randint(0,4))

y = load_data(np.asarray(mock_data), np.asarray(mock_data), mock_output, 8)
assert y[0].shape == (5, 6400)
assert y[1].shape == (5, 6400)
assert y[2].shape == (5, 4)
assert len(y) == 3
```

Test load data method CNN returns the expected data shape

In [17]:

```
from random import randint
mock_data = []
mock_output = [[1,1,1,1],[2,2,2,2],[3,3,3,3],[4,4,4,4]]

for i in range(400):
    mock_data.append([])
    for j in range(4):
        mock_data[i].append(randint(0,4))

x = load_data_cnn(np.asarray(mock_data), np.asarray(mock_data), mock_output, 2)
assert x[0].shape == (4, 100, 4)
assert x[1].shape == (4, 100, 4)
assert x[2].shape == (4, 4)
assert len(x) == 3

mock_data = []
mock_output = [[1,1,1,1],[2,2,2,2],[3,3,3,3],[4,4,4,4], [5,5,5,5]]

for i in range(500):
    mock_data.append([])
    for j in range(64):
        mock_data[i].append(randint(0,4))

y = load_data_cnn(np.asarray(mock_data), np.asarray(mock_data), mock_output, 8)
assert y[0].shape == (5, 100, 64)
assert y[1].shape == (5, 100, 64)
assert y[2].shape == (5, 4)
assert len(y) == 3
```

Test dimensionality reduction returns expected data size and shape

In [19]:

```

mock_data = []
for i in range(100):
    mock_data.append([])
    for j in range(40):
        mock_data[i].append(randint(0,4))

mock_data = np.asarray(mock_data)

assert mock_data.shape == (100,40)
x = perform_dimensionality_reduction(mock_data, mock_data)
assert len(x) == 2
assert x[0].shape == (100, 4)
assert x[1].shape == (100, 4)

mock_data2 = []

for i in range(100):
    mock_data2.append([])
    for j in range(640):
        mock_data2[i].append(randint(0,4))

mock_data2 = np.asarray(mock_data2)

assert mock_data2.shape == (100,640)
y = perform_dimensionality_reduction(mock_data2, mock_data2)
assert len(y) == 2
assert y[0].shape == (100, 64)
assert y[1].shape == (100, 64)

```

Test data sets are split into correct sizes for test and train

In [20]:

```

mock_data = []
mock_data_outputs = [[0,0,0,0],[0,0,0,0],[0,0,0,0],[0,0,0,0],[0,0,0,0],[0,0,0,0],[0,0,
0,0],[0,0,0,0],[0,0,0,0],[0,0,0,0]]
for i in range(10):
    mock_data.append([])
    for j in range(40):
        mock_data[i].append(randint(0,4))

mock_data = np.asarray(mock_data)

x = split_test_train(mock_data, mock_data, mock_data_outputs, 0.4)
assert len(x) == 6
assert x[0].shape == (6,40)
assert x[1].shape == (4,40)
assert x[2].shape == (6,40)
assert x[3].shape == (4,40)
assert len(x[4]) == 6
assert len(x[5]) == 4

```

Test MLP is created as expected from generate MLP method

In [21]:

```

layers = (200,10)
shape = (40,)
inputA = Input(shape=(40,))
inputB = Input(shape=(40,))

x = Dense(200, activation="relu")(inputA)
x = Dropout(0.3)(x)
x = Dense(10, activation="relu")(x)
x = Dropout(0.3)(x)
magnitude_test = Model(inputs=inputA, outputs=x)
magnitude = create_mlp(shape, layers, False, "relu")

assert magnitude.layers[1].weights[0].shape == magnitude_test.layers[1].weights[0].shape
assert magnitude.layers[3].weights[0].shape == magnitude_test.layers[3].weights[0].shape
assert len(magnitude.layers) == len(magnitude_test.layers)

y = Dense(200, activation="relu")(inputB)
y = Dropout(0.3)(y)
y = Dense(10, activation="relu")(y)
y = Dropout(0.3)(y)
phase_test = Model(inputs=inputB, outputs=y)
phase = create_mlp(shape, layers, False, "relu")

assert phase.layers[1].weights[0].shape == phase_test.layers[1].weights[0].shape
assert phase.layers[3].weights[0].shape == phase_test.layers[3].weights[0].shape
assert len(phase.layers) == len(phase_test.layers)

combined = concatenate([magnitude.output, phase.output])
z = Dense(10, activation="relu")(combined)
z = Dense(2, activation="linear")(z)
model_test = Model(inputs=[magnitude.input, phase.input], outputs=z)
model = combine_models(phase, magnitude, (10,))

assert model.layers[2].weights[0].shape == model_test.layers[2].weights[0].shape
assert model.layers[3].weights[0].shape == model_test.layers[3].weights[0].shape
assert model.layers[6].weights[0].shape == model_test.layers[6].weights[0].shape
assert model.layers[7].weights[0].shape == model_test.layers[7].weights[0].shape
assert model.layers[11].weights[0].shape == model_test.layers[11].weights[0].shape
assert model.layers[12].weights[0].shape == model_test.layers[12].weights[0].shape
assert len(model.layers) == len(model_test.layers)

```

Test CNN is created as expected from generate CNN method

In [22]:

```

shape=(40,1)
filters=(64,64)
layers=(100, )
inputA = Input(shape=(40,1))
inputB = Input(shape=(40,1))

x = Conv1D(filters=64, kernel_size=3, activation='relu')(inputA)
x = Conv1D(filters=64, kernel_size=3, activation='relu')(x)
x = Dropout(0.5)(x)
x = MaxPooling1D(pool_size=2)(x)
x = Flatten()(x)
x = Dense(100, activation="relu")(x)
magnitude_test = Model(inputs=inputA, outputs=x)
magnitude = create_1d_cnn(shape, False, filters, layers, 'relu')

assert magnitude.layers[1].weights[0].shape == magnitude_test.layers[1].weights[0].shape
assert magnitude.layers[2].weights[0].shape == magnitude_test.layers[2].weights[0].shape
assert magnitude.layers[6].weights[0].shape == magnitude_test.layers[6].weights[0].shape
assert len(magnitude.layers) == len(magnitude_test.layers)

y = Conv1D(filters=64, kernel_size=3, activation='relu')(inputB)
y = Conv1D(filters=64, kernel_size=3, activation='relu')(y)
y = Dropout(0.5)(y)
y = MaxPooling1D(pool_size=2)(y)
y = Flatten()(y)
y = Dense(100, activation="relu")(y)
phase_test = Model(inputs=inputB, outputs=y)
phase = create_1d_cnn(shape, False, filters, layers, 'relu')

assert phase.layers[1].weights[0].shape == phase_test.layers[1].weights[0].shape
assert phase.layers[2].weights[0].shape == phase_test.layers[2].weights[0].shape
assert phase.layers[6].weights[0].shape == phase_test.layers[6].weights[0].shape
assert len(phase.layers) == len(phase_test.layers)

combined = concatenate([magnitude.output, phase.output])
z = Dense(10, activation="relu")(combined)
z = Dense(2, activation="linear")(z)
model_test = Model(inputs=[magnitude.input, phase.input], outputs=z)
model = combine_models(phase, magnitude, (10,))

assert model.layers[2].weights[0].shape == model_test.layers[2].weights[0].shape
assert model.layers[3].weights[0].shape == model_test.layers[3].weights[0].shape
assert model.layers[4].weights[0].shape == model_test.layers[4].weights[0].shape
assert model.layers[5].weights[0].shape == model_test.layers[5].weights[0].shape
assert model.layers[12].weights[0].shape == model_test.layers[12].weights[0].shape
assert model.layers[13].weights[0].shape == model_test.layers[13].weights[0].shape
assert model.layers[15].weights[0].shape == model_test.layers[15].weights[0].shape
assert model.layers[16].weights[0].shape == model_test.layers[16].weights[0].shape
assert len(model.layers) == len(model_test.layers)

```

Test metrics returned as expected

In [23]:

```
mock_output = np.asarray([[1,1,2,2],[2,2,3,3],[3,3,4,4], [5,5, math.nan, math.nan]])
mock_outut_cleaned = np.asarray([[1,1,2,2],[2,2,3,3],[3,3,4,4]])
x = MUSIC_metrics(mock_output)

assert len(x) == 3
assert x[0] == mean_absolute_error(mock_outut_cleaned[:,0:2], mock_outut_cleaned[:,2:4])
assert x[1] == mean_squared_error(mock_outut_cleaned[:,0:2], mock_outut_cleaned[:,2:4])
assert x[2] == [3]
```