1. **Hidden layer equation**

(learning rates: =0.001; =0.001).

(5)

(6)

Convert polar coordinate equation (r and θ ) to complex domain according to ()

(7)

(8)

(8a)

Where Z is the complex domain activation of hopf oscillator. is the real part of oscillator activation, is the imaginary part of oscillator activation.

*Forward propagation:*

(9)

Where is the feedforward weight between oscillatory layer to 1st hidden layer. These feedforward weights are initialized in complex domain. It has both real () and imaginary part ().

(10)

Where is the feedforward weight between 1st hidden layer to output layer. These feedforward weights are initialized in complex domain. It has both real () and imaginary part ().

(11)

Where is the product of complex oscillatory activation () and (eqn. 12) It has both real() and imaginary part ().

(12)

Both and are passed through tanh function separatedly. Real part of sigmoid activation () and () (: imaginary part of 1st tanh activation) and is the total activation of 1st hidden layer.(eqn. 13 & eqn, 14).

(13)

(14)

Where is the product of 1st hidden layer activation () and (where is the 1st hidden to output node weight, , are the real and imaginary part of )(eqn. 15) It has both real() and imaginary part ().

(15)

(16)

At output node (eqn. 17) we consider the only real part of , which is . And also at output layer we have tanh neuron.

(17)

*Backpropagation:* The complex domain backpropagation has been adapted from [1].

**Loss at every time step,**

(18)

Where , is the desired (target) signal.

(19)

(20)

(21)

(22)

**Rewrite the Activation function:**

**Sigmoidal activation function:**

(23)

Put , ,