Master Thesis

Tuning of the Optical Beamforming Networks

Delft University of Technology

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Outline

Next Section

Project Overview

Figure: Mechanical Antenna on Aeroplane

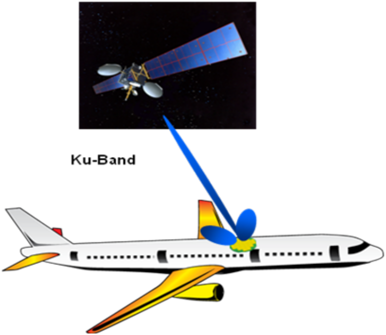


Figure: Phased Array Antennas on Aeroplane

Project Overview

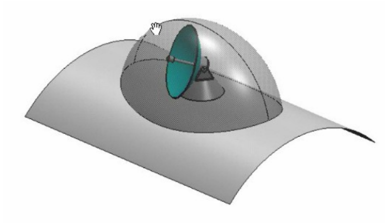


Figure: Mechanical antenna

Figure: Phased array antennas

Phased Array Antennas

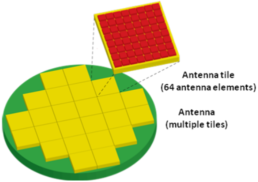
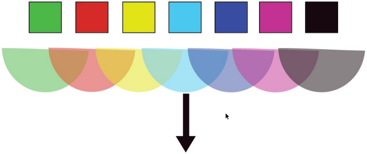
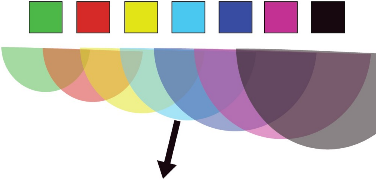


Figure: PAA configuration





OBFN Chip

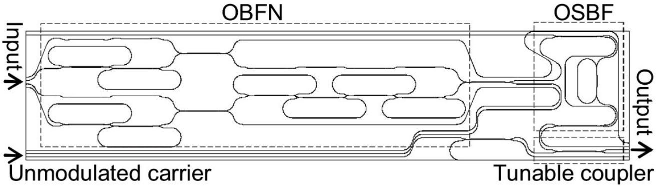


Figure: Waveguide layout of an integrated beamformer chip

Optical Ring Resonator (ORR)

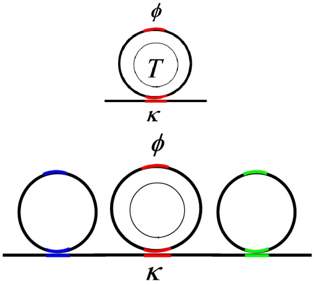


Figure: Optical Ring Resonator Configuration

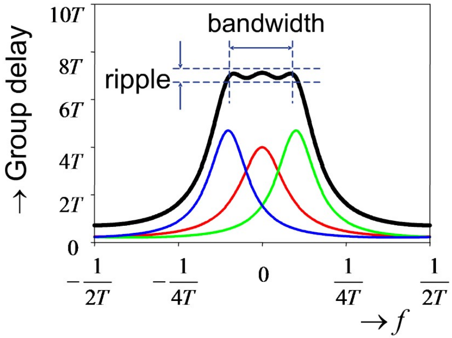


Figure: Delay, ripple, and bandwidth graph

Next Section

Parameters to be Tuned

Transmit/receive angle(s)

$\downarrow$

Group delays, amplitudes

$\downarrow$

Optical parameters

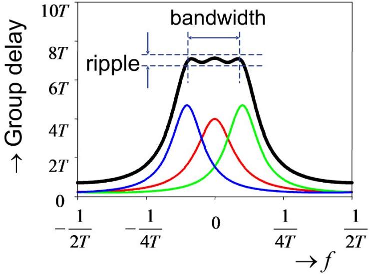
$\downarrow$

Voltages

Parameters to be Tuned: Optical Parameters

Parameters to be tuned to get the desired goals are the optical parameters : κ, ϕ, and T of each ORR

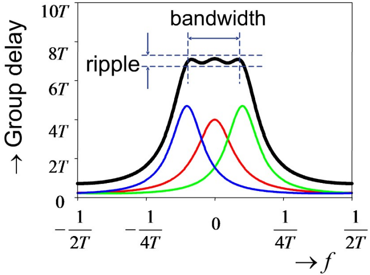
Desired Goals of Tuning



Goals: Group delays, ripple and bandwidth

- **Group delays** : a certain value, depends on the angle of signal
- **Ripple** : flat
- **Bandwidth** : alligned with the spectrum of the modulated optical signal

Desired Goals of Tuning



Tradeoff!

There is a **tradeoff** between the group delays, ripple, bandwidth and the number of ORR needed.

Tuning Methods - NLP

Definition

Search for the parameters that minimize the cost function μ subject to several constraints.

The usual notation of this problem is as follows

$$\min_x \mu(x)$$
$$s.t$$
$$\mathbf{l} \leqslant \mathbf{x} \leqslant \mathbf{u}$$
$$g_i(x) = 0$$
$$g_i(x) \leqslant 0$$

It is implemented in the *fmincon* function of MATLAB

Tuning Methods - NLP - Cost Functions

Delay Criterion

Delay Criterion can be used as a cost function.

$$\mu = \sum_k (\tau_{total}(f_k) - D)^2$$

with

$$\tau_l(f) = \frac{\kappa_l T}{2 - \kappa_l - 2\sqrt{1 - \kappa_l}\cos(2\pi f T + \phi_l)}$$

and D is the desired delay value

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Tuning Methods - NLP - Cost Functions

Phase Criterion

Phase Criterion can be used as a cost function.

$$\mu = \sum_n \left(\psi_{total}(f_0 + f_{IF,n}) + 2\pi D(f_0 + f_{IF,n})\right)^2$$

with

$$\psi(f) = \arctan\left(\frac{\sin(2\pi fT + \phi_l)}{\sqrt{1-\kappa_l} - \cos(2\pi fT + \phi_l)}\right) - \arctan\left(\frac{\sqrt{1-\kappa_l}\sin(2\pi fT + \phi_l)}{1 - \sqrt{1-\kappa_l}\cos(2\pi fT + \phi_l)}\right)$$

and D is the desired delay value

Tuning Methods - NLP - Cost Functions

Power Criterion

Power Criterion can be used as a cost function.

$$\mu = \sum_{n} [P_{ideal} - P_{actual}]^2$$

with

$$P_{ideal} = \sum_{m=1}^{M} a_m \left| H_m(f_o + f_{IF,n}) \right|$$

$$P_{actual} = \left| \sum_{m=1}^{M} a_m \left| H_m(f_o + f_{IF,n}) \right| \exp(j(\psi_{total,m}((f_o + f_{IF,n})) + D_m(f_o + f_{IF,n}))) \right|$$

and D_m is the desired delay value

Proposed Tuning Methods - Machine Learning

Definition

Machine learning concept can be used to train the neural networks to get the optimum parameters which minimize the error (cost function μ)

Cost function μ that can be used is Power Criterion because it is measurable so it is easy to be compared to the desired one.

Next Section

Cost Functions

Power Criterion

Power Criterion can be used as a cost function.

$$\mu = \sum_{n} \left[P_{ideal} - P_{actual}\right]^2$$

or, for mathematical convenience, following μ can be used

$$\mu = \sum_{n} \frac{1}{2} \left[P_{ideal} - P_{actual}\right]^2$$

Parameter Gradients

Definition

The gradient is necessary to determine in which direction will the optimization process go. Since the cost function is an error function of the desired and actual result, the gradient needed is a rate of change of error w.r.t change of parameters.
In machine learning concept, Backpropagation algorithm can be used to find the rate of change of error w.r.t change of parameters.

Input and Output of Neural Network

Definition

Input can be the desired value of power.
Output can be the actual value of power produced.
This means the Neural Network that is used is the network that is able to reproduce its input at the output layer. This concept is called Autoencoder.

Dropout Regularization

Definition

One of most common problem in neural network is overfitting, means the system learn over fit to the trained data, which will make the system will not have good result when new test data is introduced. This problem is handled by a stochastic training method called Dropout regularization.