ARTIFICIAL NEURAL NETWORK CALCULATES BACKWARD WAVE OSCILLATOR PARAMETERS RELIABLY FOR PULSED ACCELERATORS

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Abstract

Backward wave oscillator (BWO) is a high power microwave-generating device, which is harmful for people and capable of damaging electronic equipments. It is mandatory to shield the critical control systems and instrumentation especially of strategic importance against such High Power Microwaves (HPM). To know the effects of HPM on human being and electronics, BWO is an efficient device, driven by pulsed accelerator electron beam of high power in Giga-Watt (GW) regime. These intense power electron beam pulses are obtained by an impulse generator followed by a pulse forming line and coupled to a field emission diode. Thereafter the electron beam interacts with electromagnetic modes of the wave-guide and produces microwaves in the frequency range of 1-20 GHz. Resultant frequency depends upon the wave-guide parameters, beam current, beam geometry etc. With analytical techniques, design optimization is cumbersome and slow. Every time the simulation program is run, it takes nearly 6 to 8 hours to generate a single result.Artificial Neural Networks (ANNs) have been used successfully in various applicatioins. A trained ANN generates its output in a fraction of a second. In this study ANN was used to calculate BWO frequency. The training of the ANN takes about half an hour. Once trained, the ANN takes plasma density, wave number and ripple amplitude as inputs and calculates the BWO frequency in a fraction of second. The frequencies calculated by ANN and that by simulation program differ at the most by about 2%. This shows that ANN is a reliable substitute for repeated run of simulation program.

INTRODUCTION

Accelerator driven Relativistic backward wave oscillators (BWO) are promising candidate as source of High Power Microwave (HPM) radiation. They were studied extensively in the last two decades and detailed overview of this research is presented in [1]. Microwave radiation in a relativistic BWO is produced by interaction between a pulsed accelerator relativistic electron beam and an electromagnetic field of a slow wave structure. Usually, the beam is generated by a field emission gun and guided by a strong homogeneous magnetic field. Metallic periodic structures are widely used as slow wave structure. In the construction of such device it is necessary to examine coupling coefficients of the electron beam with the fields of the slow wave structure (SWS), the solution of mode competition, and determination of the electrical strength of the SWS. The most complete analysis of theses problems is possible only for the dispersion description of the SWS.In the last two decades, significant research effort was directed in increasing output power and operating frequency. In most research and studies different wave-guide and beam parameters were assumed. In order to meet the requirement of maximum peak power, it is essential to explore accurate but fast technique of the dispersion relation's calculation for different wave-guide and beam parameters. This paper extends on our previous work and establishes a dispersion relation for a pulsed sheet beam driven backward wave oscillator in which a rectangular rippled wall wave-guide is used as SWS.

The generally believed superior cognitive capabilities of an Artificial Neutral Network (ANN) are being utilized these days for various event characterizations /classifications exercise in a wide range of fields. ANN had been used for estimating channel power distribution of a 220 MWe Pressurised Heavy Water Reactor [9]. An interesting and novel application of ANN is demonstrated in this work. It has been found that a properly trained ANN can be employed to reliably estimate the generating frequency of a BWO, depending upon the different wave-guide and pulsed accelerator beam parameters. A comparison of the results obtained by the ANN and the simulation program is presented at the end of this paper.

DISPERSION RELATION

Consider the interaction between pulsed accelerator sheet electron beam of density N_b in axially rippled infinitely long rectangular wave guide as considered in ref. [8]. The whole geometry of the slow wave structure (SWS) along with the sheet beam is immersed in a strong longitudinal magnetic field ideally having infinite magnitude.

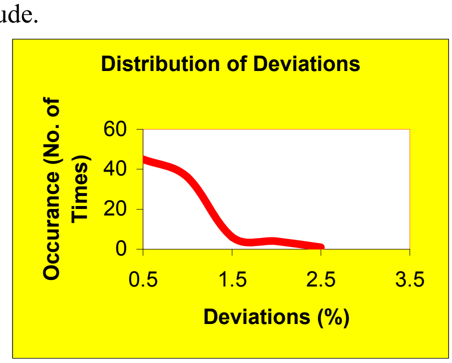

Figure 1: Deviations of the ANN calculated frequencies from the desired ones

Under this assumption the electron motions are 1-D in the axial direction. Using the Maxwell's equation and solving them by using the boundary conditions of waveguide we calculated the 3x3 matrix type dispersion relation as shown in Fig.1.

By substituting the values of waveguide parameters as width of the waveguide, ripple amplitude, thickness of the waveguide, plasma density inside the waveguide etc. we have got the data for resultant generating frequency.

In recent years, there has been a great deal of interest in artificial neural network (ANN) and its applications. The ability of ANN to handle non-linear data interpretations and their ease of implementation has encouraged their successful use in such diverse areas as physics, neurobiology, psychology, and computer research. ANN is basically a computation technique for recognizing data patterns. It consists of simple processing units called neurons or nodes, which bear resemblance to biological neurons. Each node is connected to the other nodes in the network by unidirectional connection of different strength, called weights.

COMPARISON OF NUMERICAL AND ANN DATA

The weighted inputs are summed and applied to a non-linear transfer function to produce an output. The nodes are usually arranged in a series of layers, which are bounded by input and output layers. Sandwiched between these two nodes, there are one or more hidden layers, which are provided with a structure compatible with the complexity of the problem at hand.

The ANN software package named BIKAS has been utilized for investigation of generating frequency for the BWO. The optimum performance was achieved with the following settings of various ANN parameters offered by this software. An input layer with 3 processing nodes, one hidden layers with 10 nodes and one output layer with one node. The training of the network was carried out by presenting plasma density, wave number and ripple amplitude to its 3 input nodes. There were 188 data sets. Half of them were used for training and the remaining half were used for testing.

The training and the test data were obtained by running the simulation program. During the training process, the interconnection weights of the network were iteratively adjusted until the network responded with minimum error, i.e. the ANN calculated frequencies closely matched with the frequencies obtained by simulation

program. Following table-1 presents a sample of the results obtained by the ANN. Figure 2 shows the distribution of deviations of the ANN calculated frequencies from the corresponding desired frequencies.

The distribution of deviations is almost symmetrical around zero. Most of the deviations are around zero. The maximum deviation obtained in this study was ~3%. When the experiment of re-training and testing of the ANN was repeated, the deviations were of similar nature and magnitude. It shows the ruggedness and reliability of the ANN.

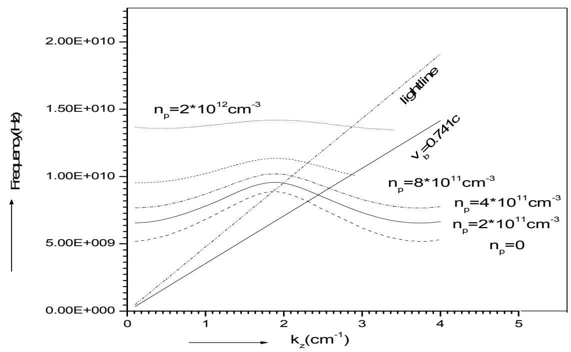

Figure 2: The calculated effect of varying the plasma density on the corrugatedWave-guide dispersion(y\-(0)=1.445cm, \g(e)=0.225cm,k\-(w)=3.76cm\+(-1))

CONCLUSION

A feasibility study has been carried out to access the potential of an Artificial Neural Network (ANN) for determining the generating frequency for a Backward Wave Oscillator (BWO) driven by pulsed accelerator sheet electron beams. The result obtained by ANN matched with those obtained with numerical technique and simulation program. A maximum deviation of ~3 % was noticed between the frequencies obtained by ANN and numerical technique. It is, therefore, concluded that ANN is reliable and suitable candidate for fast calculation of BWO frequencies.

ACKNOWLEDGEMENT

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Table 1: Comparison data obtained through numerical calculation and simulation through ANN

Plasma density n_p	Wave number K_z	Ripple amplitude h	Desired Frequency (Hz)	ANN Frequency (Hz)	Percentage Deviation (%)
0	2	0.225	$8.79*10^9$	$7.37*10^9$	0.5048
$2*10^{11}$	2	0.225	$9.51*10^9$	$9.206*10^9$	0.5525
$4*10^{11}$	2	0.225	$1.02*10^{10}$	$1.017*10^{10}$	0.4466
$6*10^{11}$	2	0.225	$1.42*10^{10}$	$1.379*10^{10}$	0.0307
$8*10^{11}$	2	0.225	$11.13*10^{10}$	$1.175555*10^{10}$	0.6827