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SHORT COMMUNICATION

Automatic Dispersion Measurements of Helical Slow-Wave Structure

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ABSTRACT

An experimental setup for computer-controlled automatic measurement of dispersion characteristics of helical slow-wave structures (SWSs) has been described. A non-resonant perturbation technique was employed for this purpose. The dispersion characteristics of a practical X-Ku band helical SWS were studied using this experimental setup. The experimental results have shown good agreement with analytical results obtained using an equivalent circuit approach for an X-Ku band helix SWS.

NOMENCLATURE

α	Electric polarisability
α_m	Magnetic polarisability
β	Axial propagation constant
	Permittivity
E	Electric field strength
Γ	Complex reflection coefficient
H	Magnetic field strength
μ	Permeability
P	Incident power at the measurement port
	Phase velocity
ω	Angular frequency

INTRODUCTION

Traveling-wave tubes (TWTs) continue to be of importance in electronic warfare applications due to their high gain and wide bandwidth capabilities. A helix slow-wave structure (SWS), which exhibits very little dispersion over a wide bandwidth, is ideal for these tubes. A helix SWS is characterised by its dispersion behaviour, i.e., variation of phase velocity with fequency (ω-β characteristics). The interaction impedance and characteristic impedance of the dispersion behaviour of helix SWSs can be analysed either using an equivalent circuit approach or carrying out field analysis of the structure. However, there is need for a simple, efficient, fast and accurate technique for studying the dispersion characteristics of the practical SWSs due to difference in theoretical prediction and actual values owing to certain assumptions made in the theory and certain imperfections in the assembly of actual SWSs.

The measurement of dispersion characteristics of a SWS is generally carried out under cold test conditions (i.e. in the absence of electron beam) using following two techniques: (i) resonant perturbations technique and (ii) non-resonant

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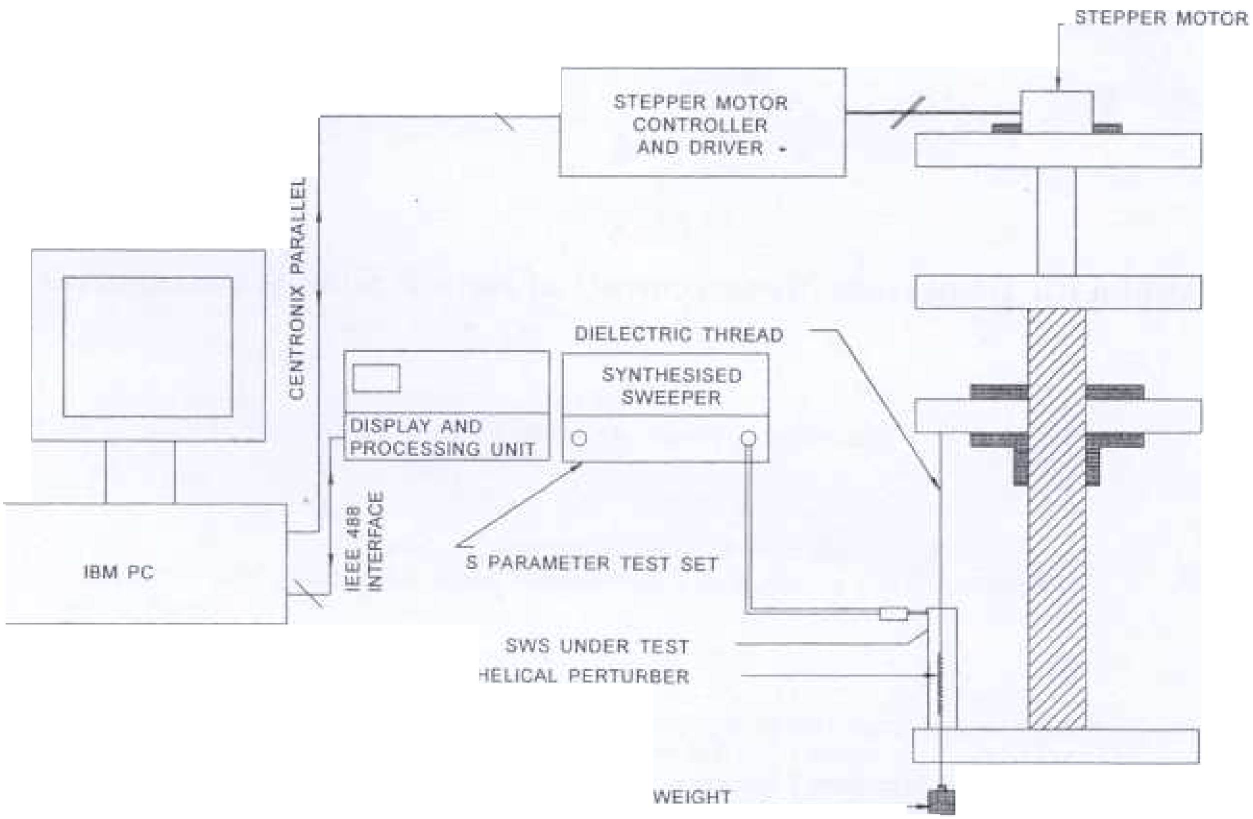

Figure 1. Experimental setup for automatic non-resonant perturbation measurements

perturbation technique. Since helical SWSs are non-resonant traveling-wave structures, the non-resonant perturbation technique is generally preferred for such type of structures. The non-resonant pertubation theory proposed by Steele[1], and modified suitably for helical SWS by Leggara[2], has been adopted here.

In this paper, the development of an automatic computer-aided measurement setup for the characterisation of helical SWS using a non-resonant perturbation technique has been described. Further work is continuing on this aspect. An X-Ku band helix TWT SWS was used for testing the system. A comparison of measured dispersion characteristics was made with those predicted by circuit model[3]. This setup can also be used for the measurement of interaction impedance characteristics of SWS using an appropriate theory.

2. THEORY OF MEASUREMENT

The non-resonant pertubation technique forms the basis for the measurement of β. Here, the change in Γ at the measurement port of a non-resonant microwave circuit is related to the complex electric and magnetic field components at a given position in the circuit due to the insertion of a perturber as

$$\Gamma = (\Gamma - \Gamma_o) = (\omega/2)\left\{\varepsilon\alpha_c E^2 - \mu\alpha_m H^2\right\}/2P_{in}$$

Assuming that the right hand side of Eqn (1) is proportional to the square of a generalised field quantity[2], one can write Eqn (1) as

$$|\Delta\Gamma|\,\mathrm{Exp.}(j\varphi)\,\alpha\,|\rho|^2\,\mathrm{exp.}(-2j\beta z)$$

where ϕ is the phase of the reflected signal. Differentiating Eqn (2) wrt z and equating the imaginary terms, one gets

$$\beta = -\,0.5(d\phi/dz) \qquad (3)$$

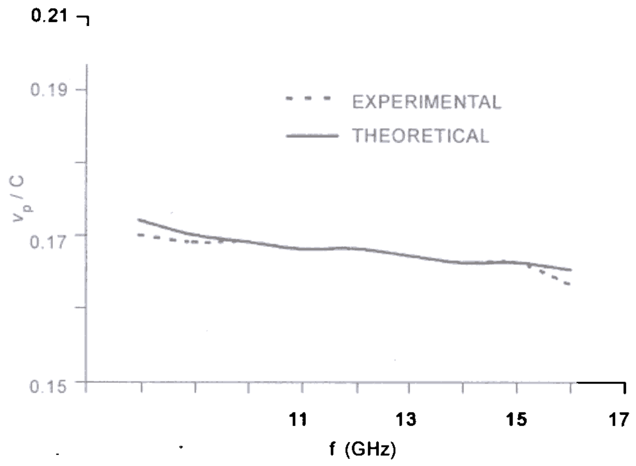

Figure 2. Dispersion characteristics of X-Ku band slow-wave structure.

Thus, β of SWS can be obtained by measuring the phase velocity of the reflected signal as a function of distance. Since the phase velocity, V_p is related to β as $V_p = \omega / \beta$, it is computed for different frequencies using values of β.

3. TEST SETUP FOR AUTOMATIC MEASUREMENT

The experimental setup for measuring phase at various positions along the SWS has the following four main functional units, as shown in Fig.1:

(a) A mechanical fixture for holding the SWS assembly and ensuring precise coaxial movement of the perturber inside the helical SWS.

(b) A stepper motor controller and driver for movement of the perturber.

(c) A vector netword analyser (VNA) to measure the phase of the reflected signal at various frequencies as the perturber moves along the axis of SWS.

(d) A personal computer (PC) to control the stepper motor controller and the VNA.

SWS, whose dispersion characteristics are to be measured, is mounted on the base plate of the mechanical fixture. A contra-wound helix of 3 turns and of diameter equal to half of the inner diameter of the main helix with a similar pitch was used as the perturber. The pertuber is fixed on a thread attached to a central carriage and the other end of the thread is attached to a suspended weight to keep the thread taut. A computer-controlled stepper motor achieves precise step-by-step coaxial movement of the perturber inside the SWS. The L297 stepper motor controller and L298N dual bridge stepper motor driver activate the stepper motor. This controller is connected to PC through a centronix parallel port, as shown in Fig.1. PC controls the VNA through GPIB interface. A user-friendly software is written in GW basic to control the VNA and the stepper motor controller. The inputs to this software are fequency range, perturber displacement and step size. The program outputs the phase of the reflected signal at each spot frequency. The output is stored in a file and then processed to obtain the phase velocity *vs* frequency characteristics. The same setup can be used for measuring interaction impedance of SWS using phase measurement discussed above. However, validation of the results for impedance measurement is yet to be achieved.

4 RESULTS

This setup was used for measuring the dispersion characteristics of a helix SWS used in a wide band X-Ku helix TWT. The experimentally determined dispersion characteristics of SWS are shown in Fig. 2. These results are compared with the theoretical dispersion curve for the X-Ku band tube obtained using a computer program based upon the equivalent cirrcuit approach[3,4]. The experimental results are in good agreement with the theoretical results.

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