Broad bandwidth Suspending Conformal Angular Meander Line Slow Wave Structure

Tenglong He, Duo Xu, Hexin Wang,
Wei Shao, Zhanliang Wang, Zhigang Lu,
Huarong Gong, Zhaoyun Duan,
Yubin Gong*
National Key Laboratory of Science and Technology
on Vacuum Electronics.
University of Electronic Science and Technology of
China, Chengdu, China, 610054
*Email： ybgong@uestc.edu.cn

Jinjun Feng
Vacuum Electronics National Laboratory
Beijing Vacuum Electronics Research Institute
Beijing, China, 100016

Abstract: *In this paper, a wide bandwidth suspending conformal angular meander line slow wave structure (ML SWS) is proposed. By suspending the dielectric substrate, this SWS changes the e-field of microstrip that its lower surface of dielectric substrate does not connect with ground. So, it has wide bandwidth and high impedance. The simulation results show suspending conformal ML SWS has a low voltage 3800V at Ka-band. The maximum output power can reach 104W at 34GHz. The 3-dB bandwidth is7GHz that is from 32GHz to 39GHz and the maximum electron efficiency is 14%.*

Keywords: Meander line, Slow wave structures, Traveling Wave Tubes

Introduction

Traveling wave tube (TWT) is one important kind of vacuum devices in many ways, as the military electronic countermeasures, satellite communications and radar detection. With the development of the communication technology, the demand for TWTs is also increasing. High electron efficiency, broad bandwidth and miniaturization are the advance direction of TWT in the future.

In recent years, the miniaturization of SWS is part of the focuses of current research. Some planar SWSs, including microstrip mender line SWS and the planar helix with straight-edge connection, have been proposed for miniaturized TWT in ref. [1-3]. Microstrip angular log-periodic ML SWS can reach a high electron efficiency with few periods [4]. Because the angular log-periodic ML SWS is not periodic structure, its phase velocity is tapering. This structure can come true the beam velocity and phase velocity are continuously synchronized. In ref [5], we proposed a conformal microstrip ML SWS which have higher impedance than microstrip ML SWS. The conformal microstrip SWS means the shape of substrate is same as the metallic layer of SWS. But in the assembling, it will be a difficulty.

In this paper, a suspending conformal angular ML slow wave structure is proposed. It is based on the conformal microstrip ML SWS. The ML SWS is suspending in the vacuum by supporting the dielectric substrate. It can be easier fabricated an assembling than before. Depend on magnetron sputtering and laser cutting, it can be fabricated.

Description of suspending conformal meander line slow wave structure

The suspending conformal angular ML SWS is an aperiodic structure, which is constructed according to the logarithmic spirals:

$$r = ae^{b\varphi}$$

Logarithmic spirals are determined by two important parameters *a* and *b*, which *a* is the initial radius and *b* is spiral growth constant. The initial position is determined by initial radius *a* while the gap growth rate between two adjacent logarithmic spiral lines is determined by the spiral growth constant *b*. For angular log-periodic ML, the angular θ shown in Figure 1 is also taking an important role in the dispersion of this structure. The parameters of this SWS is shown in Table 1.

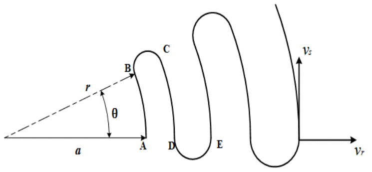

Figure 1. Angular log-periodic meander line.

As showed in Figure 2, the suspending conformal ML SWS has 30 periodic-like ML periods. Except the conformal substrate which under the metallic layer, there are two parts dielectric substrate on both sides of ML SWS. It can support the whole conformal ML SWS.

Table 1. The parameters of suspending conformal ML SWS

Parameter	*Value*
a	*90 mm*
b	*0.0003*
□	*1°*
w (width)	*0.07 mm*
t (substrate thickness)	*0.2 mm*

978-1-5386-8288-3/20/$31.00 ©2020 IEEE

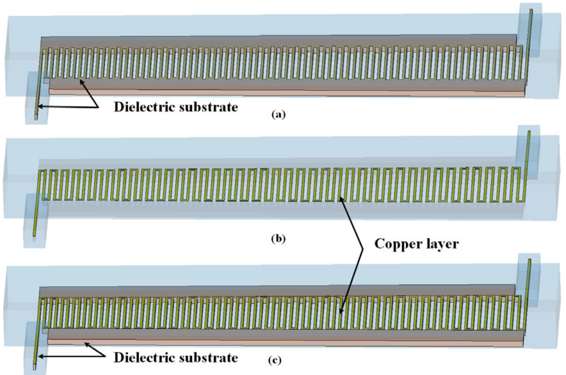

Figure 2. (a) The dielectric substrate and (b) the copper layer of (c) suspending conformal angular ML SWS.

Figure 3 shows the dispersion characteristics of different periods. From the shortest period to the longest period, the normalized phase velocity of these periodic-like ML periods is gradually decreasing. The normalized phase velocity of 1st period is 0.05 larger than that of 15th period. Similarly, normalized phase velocity of 15th period and 30th period has same gap. Therefore, this aperiodic SWS has a decreasing normalized phase velocity. The average impedance characteristics of the suspending ML SWS is given in Figure 4. Suspending substrate make the coupling impedance of SWS to increase.

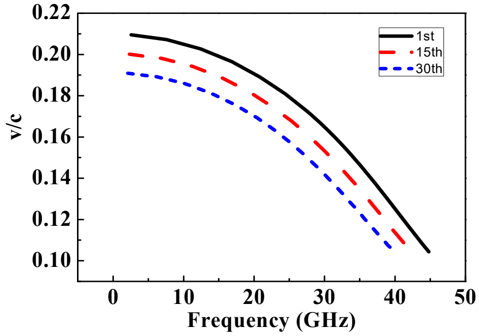

Figure 3. The dispersion characteristics of different periodic structures.

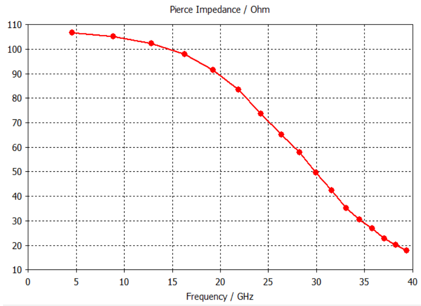

Figure 4. The average coupling impedance of the suspending confomal angular ML SWS.

Simulation Results

We simulated a whole model of the SWS consisting of 30 pitches with input/output couplers on both ends. To evaluate the output performance of the Ka-band TWT with the proposed suspending conformal angular ML SWS, the 3-D particle-in-cell (PIC) CST Particle Studio simulator is used.

According to the dispersion characteristics of this kind of SWS, the operating voltage and current is 3800V and 0.2A, respectively. For stable beam transportation, the focus magnetic field is set to 0.4T. Transversal dimensions of the beam are 0.2 mm×1.6 mm.

In Figure 5, we can see that the maximum output power and gain are 104 W and 23 dB at 34 GHz, respectively, when we input a 0.5W signal. The output signal is stable over the entire frequency range and we observe a clean single-frequency spectrum without any spurious mode excitation. The 3-dB bandwidth is from 32GHz to 39GHz. The electron efficiency is from 6% to 14%.

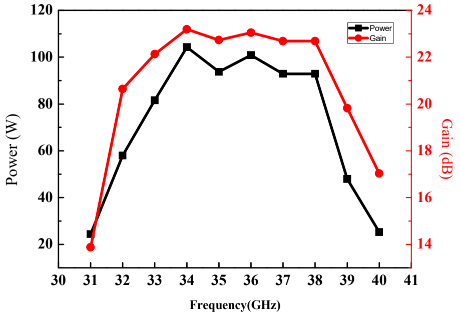

Figure 5. The output power and gain verse frequency.

Conclusion

In this paper, broad bandwidth suspending conformal ML SWS is proposed. It is an aperiodic structure and phase velocity gradient structure. Each period has different phase velocity and the phase velocity difference between adjacent periods are constant.

The 3-D PIC simulation yields a signal gain of nearly 23dB. The operating voltage of this kind of TWT is 3800V, which can produce 104W output power at 34GHz. The 3-dB bandwidth is 7GHz. The amplification frequency waveband can be easily tuned by changing the beam voltage. So, suspending dielectric substrate is proved to be an effective method to realize a high gain and broad bandwidth in the short period number.

Acknowledgments

This work is supported by National Natural Science Foundation of China under (Grant Nos. 61531010 and 61921002) and Science and Technology on High Power Microwave Laboratory Fund (Grant No. 6142605180201)

References

[1] Shen F, Wei Y, Yin H, et al. A novel V-shaped microstrip meander-line slow-wave structure for W-band MMPM[J]. IEEE Transactions on Plasma Science, 2012, 40(2): 463-469.

[2] Wang S, Aditya S, Xia X, et al. On-Wafer Microstrip Meander-Line Slow-Wave Structure at Ka-Band[J]. IEEE Transactions on Electron Devices, 2018, 65(6): 2142-2148.

[3] Chua C, Tsai J M, Aditya S, et al. Microfabrication and characterization of W-band planar helix slow-wave structure with straight-edge connections[J]. IEEE Transactions on Electron Devices, 2011, 58(11): 4098-4105.

[4] Wang S, Gong Y, Wang Z, et al. Study of the symmetrical microstrip angular log-periodic meander-line traveling-wave tube[J]. IEEE Transactions on Plasma Science, 2016, 44(9): 1787-1793.

[5] He T, Wang Z L, Li X, et al. Study on Silicon-based Conformal Microstrip Angular Log-periodic Meander Line Traveling Wave Tube[J]. Progress In Electromagnetics Research, 2018, 75: 29-37.