Effect of Noisy Input Signal and Electron Beam Velocity Nonuniform on Helix TWT Output Performance

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Abstract: *Due to the complex electromagnetic environment in the helix TWT, the input signal is noisy, and the velocity magnitude and direction of electron beam from the electron gun to the slow wave structure are nonuniform. A simulation model for helix TWT output performance with different noisy input signal and velocity of electron beam is established and the results show that signal-to-noise ratio (SNR) of the output signal is affected by noisy input signal, the velocity magnitude and direction. SNR decreases obviously when signal-to-noise ratio of input signal decreases.*

Keywords: helix TWT, noisy input signal, electron beam, velocity nonuniform, signal-to-noise ratio

Introduction

Traveling wave tubes (TWTs) are key devices in many microwave communication systems, due to its advantages of wide band, low noise and high gain. Noise performance parameters are important parameters for TWTs to be used in many scenarios. Due to the complex electromagnetic environment and cathode emission randomness in the helix TWT, the input signal is noisy, and the electron beam velocity nonuniform can be produced by several mechanisms [1].The effect of electron beam velocity nonuniform, consisting of velocity spread and transverse velocity components, on helix TWT output performance is analyzed [2]. However, the effect of noisy input signal haven't been discussed.

In this paper we simulate and discuss the effect of noisy input signal and velocity nonuniform of electron beam on output performance of helix TWT.

Simulation Model

A helix slow wave circuit is modeled by CST, with different noisy input signal and velocity of electron beam. Input signal, affected by Additive-White Gaussian Noise (AWGN), has been chosen in the simulation. Electron beam velocity nonuniform is represented by two parameters of the velocity magnitude fluctuation range (VMFR) of electron beam and the velocity direction fluctuation range (VDFR) of electron beam. The velocity magnitude of electron beam is expressed by the electron energy E (for example, 9600eV). The fluctuation range of velocity magnitude of electron beam VMFR represents the random distribution of electron energy in the range of [(1-VMFR%/2) E, (1+VMFR%/2) E]. To emit particles randomly distributed around their normal, the velocity direction fluctuation range (VDFR) of electron beam can be defined. If the angular spread is unequal to zero, the zenith angle theta is uniformly distributed between 0 degree and VDFR. The azimuth angle phi is uniformly distributed between 0 and 360 degree.

Results and Analysis

Effect of noisy input signal on TWT output performance: The simulation calculation of TWT is carried out when signal-to-noise ratio of input signal SNRI =32, 35, 38, 41, 47, 50, 60dB, VMFR =0 and VDFR=0°. The effect of noisy input signal on TWT output performance is analyzed. With different SNRI, the output signal is obtained by simulation, and then the spectrum is obtained by Fourier transform, which is shown in figure 1. It can be seen from figure 1 that the amplitude of the signal is not much different at the operating frequency 11GHz, and the amplitude of noise increases with the decrease of SNRI. For quantitative comparison, the gain (G) and signal-to-noise ratio (SNR) of the output signal are further calculated, as shown in figure 2. With the decrease of SNRI, the gain is almost unchanged. When SNRI = 60dB, the SNR is 46.08dB. With the decrease of SNRI, the SNR decreases obviously. When SNRI = 32dB, the SNR decreases to 39.98 dB. When signal-to-noise ratio of input signal SNRI decreases by 28dB, signal-to-noise ratio of the output signal decreases by 6.10 dB, which shows that the gain of the signal through the traveling wave tube is higher than that of the noise. It can be seen that the gain of the output signal is almost unchanged and the signal-to-noise ratio decreases obviously when signal-to-noise ratio of input signal SNRI decreases at VMFR =0 and VDFR=0°.

Effect of noisy input signal and VMFR on TWT output performance: The simulation calculation of TWT is carried out when SNRI = 47, 50, 60dB, VMFR =0, 0.01, 0.05, 0.1 and VDFR=0°. The effect of SNRI and VMFR on TWT output performance is analyzed. The gain and signal-to-noise ratio of the output signal are calculated, as shown in figure 3. While VMFR increase, the gain is almost unchanged. At SNRI = 60dB and VMFR=0, the SNR is 46.08 dB. With the increase of VMFR, the SNR decreases obviously. When VMFR=0.1, the SNR decreases to 43.18 dB, which decreases by 2.9 dB. At SNRI = 47, 50dB, With the increase of VMFR, the change range of SNR becomes small, and even sometimes the SNR increases slightly. It can be seen that the gain of the output signal is almost unchanged and SNR of the output signal is affected by noisy input signal and the velocity magnitude fluctuation range.

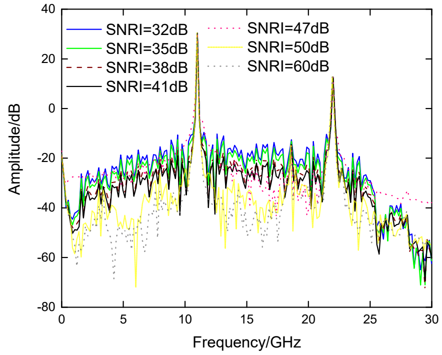

Fig.1. Spectrum Diagram of output signal at different noisy input signal

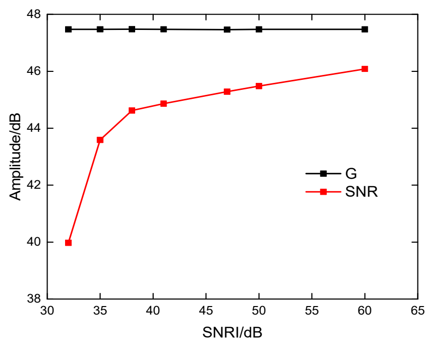

Fig.2. Gain and signal-to-noise ratio of output signal at different noisy input signal

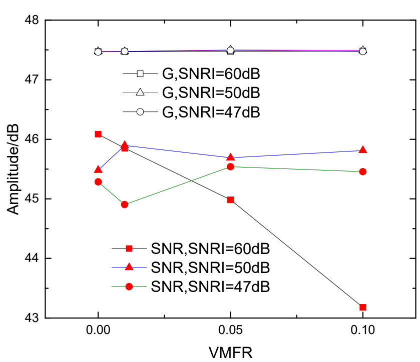

Fig.3. Gain and SNR of output signal at different noisy input signal and velocity magnitude fluctuation range

Effect of noisy input signal and VDFR on TWT output performance: The simulation calculation of TWT is carried out when SNRI = 50, 60dB, VDFR =0°, 0.01°, 0.05°, 0.1° and VMFR=0. The effect of SNRI and VDFR on TWT output performance is analyzed. The gain and signal-to-noise ratio of the output signal are calculated, as shown in figure 4. While VDFR increase, the gain is almost unchanged. At SNRI = 60dB and VDFR=0°, the SNR is 46.08 dB. With the increase of VDFR, the SNR decreases obviously. When VDFR=0.1°, the SNR decreases to 38.35 dB, which decreases by 7.73dB. At SNRI = 50dB and VDFR=0°, the SNR is 45.48 dB. With the increase of VDFR, the SNR also decreases obviously. When VDFR=0.1°, the SNR decreases to 36.47 dB, which decreases by 9.01dB. It can be seen that the gain of the output signal is almost unchanged and the signal-to-noise ratio decreases obviously when the velocity direction fluctuation range increases at VMFR =0 and SNRI = 50dB or 60dB.

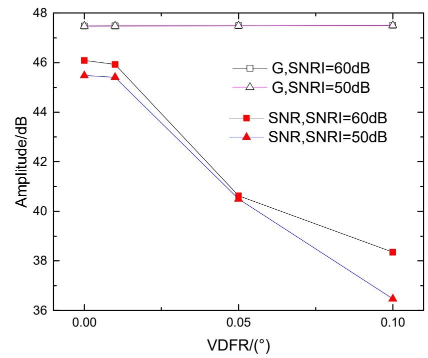

Fig.4. Gain and SNR of output signal at different noisy input signal and velocity direction fluctuation range

Conclusion

Input signal is affected by Additive-White Gaussian Noise (AWGN). The velocity nonuniform of electron beam is represented by two parameters of the velocity magnitude fluctuation range (VMFR) and the velocity direction fluctuation range (VDFR). A simulation model for helix TWT output performance with different noisy input signal and electron beam velocity is established. The gain of the output signal is almost unchanged. Signal-to-noise ratio (SNR) of the output signal decreases obviously when signal-to-noise ratio of input signal SNRI decreases at VMFR =0 and VDFR=0°. When SNRI = 32dB, the SNR decreases to 39.98 dB, which decreases by 6.10 dB, compared to that of SNRI = 60dB at VMFR =0 and VDFR=0°. With the increase of VMFR at SNRI = 60dB and VDFR=0°, the SNR decreases obviously. When VMFR=0.1, the SNR decreases to 43.18 dB, which decreases by 2.9 dB. However, with the increase of VMFR at SNRI = 47dB or 50dB, the change range of SNR becomes small. With the increase of VDFR at SNRI = 50dB or 60dB and VMFR=0, the SNR decreases obviously. When SNRI = 50dB and VDFR=0.1°, the SNR decreases to 36.47 dB, which decreases by 9.61dB, compared to that of VDFR=0° at SNRI = 60dB and VMFR =0.

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