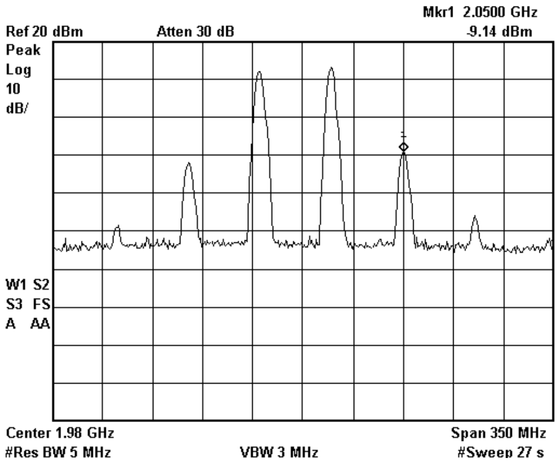
Intermodulation Suppression in a Broad Band TWT*

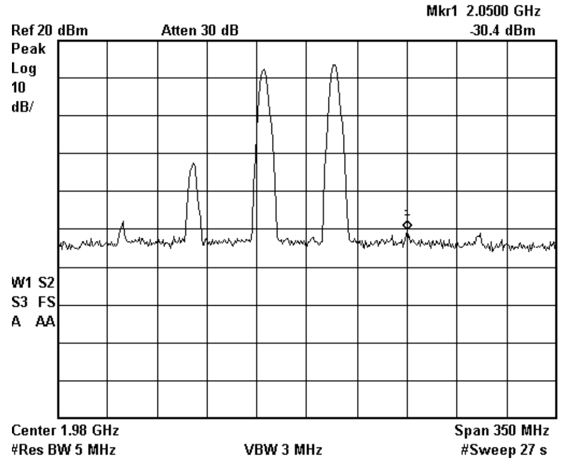
A. Singh, J. Scharer, M. Wirth, S. Bhatacharjee and J. Booske
Univ. of Wisconsin, Madison
email: singh@cae.wisc.edu, scharer@cptc.wisc.edu, mawirth@students.wisc.edu, sudeepb@engr.wisc.edu, booske@engr.wisc.edu
513 Engineering Research Building, 1500 Engineering Drive, Madison WI 53706
Tel: (608) 263-1614 Fax: (608) 265-2438

We examine methods for reducing two-tone intermodulation products in the custom-made XWING broadband traveling wave tube. Harmonic suppression and difference frequency techniques are used to demonstrate intermodulation suppression techniques and the spatial variation of their spectral evolution. Harmonic and difference frequency optimum drive levels and phase are determined which suppress the third order intermodulation product by more than 21 dB in the 2-6 GHz band. The variation of the suppression with drive level near saturation and two-tone difference frequency are examined.

IM3 reduction using the harmonic injection technique is experimentally demonstrated in a broadband TWT distributed amplifier. A recent study by Aitchison *et al.* [1] has demonstrated the effectiveness of this technique in narrowband, solid-state amplifiers at 835 and 880 MHz. They obtain substantial reduction in IM3 levels by both second harmonic and difference-frequency (1 MHz) injection techniques. Work by Datta *et al.*[2] and Wohlbier [3] describe theoretical models that predict similar behavior in TWTs. This behavior has been observed by Armstrong *et al.* [4] but not published nor studied in detail. The TWT used in this investigation, termed the XWING TWT (for eXperimental WIsconsin Northrop Grumman TWT), is a research version of a product manufactured by Northrop Grumman. This two-stage, helical TWT provides a moderate gain of 20-30 dB over a frequency range of 2-6 GHz.

The upper fundamental and harmonic frequencies were set to 2.00 and 4.00 GHz, respectively. Since the phase of the injected harmonic must be referenced with respect to the higher frequency fundamental, two Agilent 83623B synthesizers were configured to share a common 10 MHz phase reference signal. The 4.00 GHz signal was sent through a Narda 3752 phase shifter, allowing the fundamental-to-second harmonic phase relationship to be adjusted in real-time. The lower fundamental frequency of 1.95 GHz was supplied by a Wavetek 3520 synthesizer, providing a 50 MHz difference between the two drive tones. The experiment was performed for fundamental drive tones of 15 and 18dBm/tone. First, the 1.95 and 2.00 GHz fundamental drive tones were independently set to 15 dBm/tone at the TWT input tap, and the output spectrum was captured on an Agilent E4407B digital spectrum analyzer. Next, the 4.00 GHz second harmonic tone was injected at the TWT input and the phase was varied, with respect to the 2.00 GHz fundamental, to achieve the lowest IM3 level. With the phase relationship optimized, the injected harmonic amplitude was varied until a maximum suppression in the upper IM3 level was observed. This occurred with injected harmonic amplitude of -2.1 dBm or 17.1 dB below f_2. The upper IM3 was reduced by 21.3 dB, yielding an upper carrier to IM3 power ratio of 43.9 dB. The TWT output spectrum with and without harmonic injection is shown below. It can be seen that the upper IM3 is suppressed by 21.3 dB.





The experiment was repeated at higher input drive levels of 18 dBm/tone and an IM3 reduction of 24.2 dB was observed. The optimum phase of the 4 GHz injected harmonic was measured at the TWT input tap and was found to lead the 2 GHz fundamental by 47.5 degrees, with respect to the fundamental period.

We are currently examining a frequency doubler technique to obtain improved phase-locking of the second harmonic relative to the fundamental drive tone and a difference frequency suppression technique as the output levels approach saturation. In addition, the spatial variation of the spectral evolution and IM3 suppression along the helix are being examined and compared with modeling codes, and will be discussed.

REFERENCES

[1] C.S. Aitchison, M. Mbabele, M.R. Moazzam, D. Budimir and F. Ali, "Improvement of Third-Order Intermodulation Product of RF and Microwave Amplifiers by Injection," *IEEE Trans. on Microwave Theory and Techniques,* vol. 49, no. 6, pp. 1148-1154, June 2001.

[2] S.K. Datta, P.K. Jain and B.N. Basu, "Control of IM3 Distortion in Helix TWTs by Harmonic Injection – An Eulerian Hydrodynamical Study," *IEEE Trans. Electron Devices,* vol. 48, no. 1, pp. 62-67, January 2001.

[3] J. Wohlbier, University of Wisconisn, private communication(2001)

[4] C. Armstrong, Northrop Grumman Corporation, private communication (2001).

*This research is supported primarily by AFOSR Grant 49620-00-1-0088 and by DUSD (S&T) under the Innovative Microwave Vacuum Electronics Multidisciplinary University Research Initiative (MURI) program, managed by the United States Air Force Office of Scientific Research under Grant F49620-99-1-0297 and in part by the University of Wisconsin, Madison.