Correspondence

Regenerative and Pull-In Modes of Millimeter-Wave Reflex Klystron Amplifier

A reflex klystron used as an amplifier can operate in both the regenerative[1] and pull-in mode.[2] From articles published regarding reflex klystron amplification,[3–5] it appears that considerable confusion exists on this subject. It is the purpose of this communication to distinguish clearly between the two phenomena. The most readily noticeable differences occur in the frequency behavior and the input-output characteristics.

The significant difference in behavior of the two modes is clearly shown by Figs. 1 and 2. If the signal is shut off, there is no output from the tube operated in the regenerative mode; however, if the tube is operated in the pull-in mode, the tube output, pulled in with sufficient input existing, will pull away from the signal frequency to its free running frequency of oscillation, as far away as 200 Mc. Now, if the pass band of the receiver is limited, this oscillation may fall outside the frequency range covered by Figs. 1 and 2 and the two modes would appear indistinguishable from this aspect. To ascertain pull-in operation, the oscillation could then be located by tuning the receiver.

The two modes can also be distinguished by their input-output characteristics, as seen from Figs. 3 and 4. While the input-output characteristics in the regenerative mode are relatively smooth (Fig. 3), the input-output characteristics for the pull-in mode can be broken into three distinct sections, namely, free running, pull-in transition, and complete pull-in sections, as seen from Fig. 4.

In general, it was found experimentally that the gain (for comparable input levels), minimum detectable signal, and noise figure were larger for the pull-in mode than for the regenerative mode. Though as yet not conclusive, this also appears to apply for bandwidth. For example, noise figure of the pull-in mode was found to be greater than 40 db while for the regenerative mode it was less than 30 db.

Thus, by gradually varying the input level or removing the input signal altogether, the behavior of the amplifier output indicates the mode of operation.

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[1] K. Ishii "*X*-band receiving amplifier," *Electronics*, vol. 28, pp. 202–210; April, 1955.

[2] R. C. Mackey, "Injection locking of klystron oscillators," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-10, pp. 228–235; July, 1962.

[3] C. F. Quate, R. Kompfner, and D. A. Chisholm, "The reflex klystron as a negative resistance type amplifier," IRE TRANS. ON ELECTRON DEVICES, vol. ED-5, pp. 173–179; July, 1958.

[4] I. Thomas and L. Bounds, "The Investigation of the Characteristics of the KS 9-20A Reflex Klystron When Used as an Amplifier," The Mullard Radio Valve Co., Ltd., Waddon, England, D.V.T. Rept. No. U231; 1961.

[5] T. Matsumoto, M. Suzuki, and C. Funatsu, "Noise characteristics of reflex klystron amplifier," *J. Inst. Elec. Commun. Engrgs. of Japan*, vol. 46, pp. 1225–1229; September, 1963.

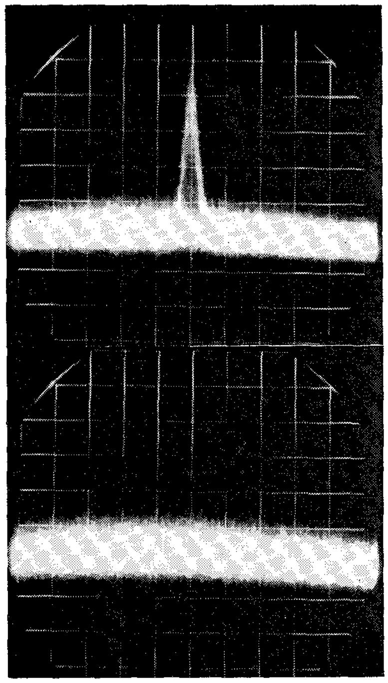

Fig. 1—Regenerative mode of reflex klystron amplifier VA-250. Upper picture shows amplified signal, gain at 70.19 kMc is 20 db, V_a=1587 v, V_r= −446 v. Lower picture shows amplifier output with no signal input. Horizontal axis is frequency swept. Input signal is 1000 cps square wave modulated and generated by a VA99 reflex klystron.

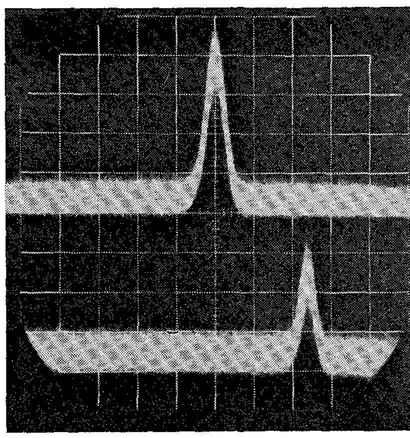

Fig. 2—Pull-in mode of reflex klystron amplifier VA-250. Upper picture shows oscillator locked into the CW signal frequency of 70.13 kMc. Gain is 10 db. Lower picture shows amplifier is now a free running oscillator at 70.17 kMc with input removed. Horizontal axis is frequency swept. V_a=1460 v and V_r= −222 v.

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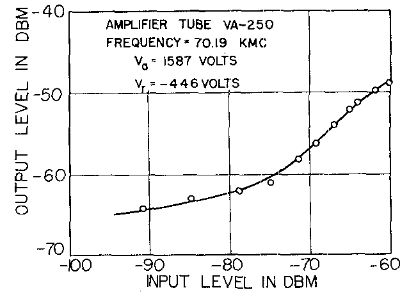

Fig. 3—Input-output characteristics of VA-250 reflex klystron amplifier operated in regenerative mode.

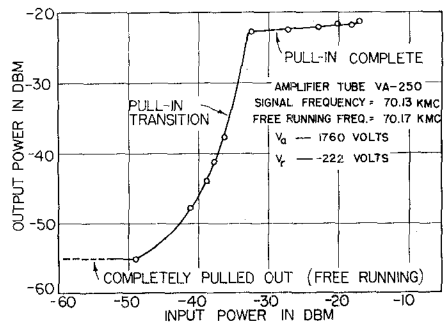

Fig. 4—Input-output characteristics of VA-250 reflex klystron amplifier operated in pull-in mode.

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An Additional Relation for "Design of Mode Transducers"

Solymar and Eaglesfield,[1] and recently Wolfert,[2] have disclosed analytical methods for designing the contours of tapered waveguide mode transducers to favor the desired modes and suppress the spurious modes. Basically, the methods are similar, but they differ in the selection of the mode weighting functions and in the methods of plotting the cross-sectional boundary contours. The

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[1] L. Solymar and C. C. Eaglesfield, "Design of mode transducers," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-8, pp. 61–65; January, 1960.

[2] P. H. Wolfert, "A wide-band rectangular-to-circular mode transducer for millimeter waves," IEEE TRANS. ON MICROWAVE THEORY AND TECHNIQUES (*Correspondence*), vol. MTT-11, pp. 430–431; September, 1963.