THE APPLICATION OF NEGATIVE FEEDBACK TO MICROWAVE BIPOLAR TRANSISTOR AMPLIFIERS

J.L.B. Walker, E. Hughes and K. Wilson

ABSTRACT

It is shown that RLC feedback between the base and collector of a microwave bipolar transistor enables one to design a single-stage unbalanced amplifier with a two-octave bandwidth (0.5 - 2.0 GHz). Over this bandwidth the measured terminal v.s.w.r.'s are within 2:1, the gain variation is ±1 dB and a noise figure ≲4.6 dB has been achieved. The advantages of feedback are:

(i) circuit design is simplified
(ii) it is more economical than a balanced approach
(iii) the gain of the amplifier can be varied by 3 dB by altering the collector current without degrading the terminal matches
(iv) feedback reduces the effect of changes in transistor s-parameters
(v) the amplifier is immune to parametric overload instabilities [1].

INTRODUCTION

Traditionally wideband (octave or greater) amplifiers are constructed in balanced form [2,3]. Whilst good v.s.w.r.'s can be achieved over 2 octaves with a balanced amplifier, it is difficult to achieve good gain flatness. This paper describes how good gain flatness over 2 octaves with v.s.w.r.'s within 2:1 can be achieved in a single-stage unbalanced amplifier by applying negative feedback.

DESIGN PHILOSOPHY

Several authors [4,5,6] have considered the application of feedback to microwave transistors. Generally, it has been lossless feedback between collector and base or emitter and ground in order to improve the noise figure or re-position the optimum noise source impedance.

Feedback is used here to achieve the greatest possible flatness of the maximum available gain over the widest possible bandwidth, whilst still maintaining a positive stability factor k. Various network topologies for both series and shunt feedback have been examined numerically and, with the above objectives, it has been found that series RLC feedback between collector and base is best. In practice, a short length of high impedance transmission line is needed in the feedback path so that the feedback components can be mounted on the substrate. Figure 1 shows the maximum available gain of a typical microwave transistor with and without feedback.

Since the 6 dB/octave roll-off in the transistor's gain is compensated for by feedback, the lossless input and output matching networks act purely as impedance transformers and their design is simplified.

The authors are with The General Electric Co. Ltd., Hirst Research Centre, Wembley, Middlesex, England.

THE FEEDBACK AMPLIFIER

The basic circuit of a single-stage feedback amplifier is shown in Figure 2.

The measured performance of this amplifier is shown in Figure 3. Because of the reduced gain the noise figure is inevitably increased compared with a non-feedback amplifier. Nevertheless, a noise figure $\leqslant$4.6 dB over 0.5 - 2.0 GHz has been achieved, but this could be improved if the transistor with feedback is fed from its optimum noise source impedance.

The gain can be reduced from 9 dB to 6 dB by reducing the collector current without degrading the v.s.w.r.'s, a feature which is impossible in non-feedback single-ended amplifiers. This shows that feedback reduces the effect of changes in transistor s-parameters; this fact has also been demonstrated numerically.

Most single-ended non-feedback bipolar amplifiers oscillate parametrically under overload [1] without special supression techniques which increase the noise figure. This feedback amplifier does not oscillate at least up to +20 dBm input signal level.

Two feedback amplifiers connected in balanced form improved the v.s.w.r.'s to $\leqslant$1.5:1 over 0.5 - 2.0 GHz.

CONCLUSIONS

For those situations in which the ultimate noise figure or terminal match is not required, an unbalanced feedback amplifier is an economical way of producing a wideband amplifier with variable gain and which is free from parametric overload instabilities.

REFERENCES

1. K. Wilson, E. Hughes and J.L.B. Walker, "Overload instabilities in microwave transistor amplifiers", Int. Solid State Circuits Conference Proceedings, pp.122-3, 1976.

2. R.S. Engelbrecht and K. Kurokawa, "A wideband low noise L-band balanced transistor amplifier", Proc. IEEE, Vol. 53, pp.237-247, 1965.

3. K. Kurokawa, "Design theory of balanced transistor amplifiers", BSTJ, Vol. 44, pp.1675-1698, 1965.

4. G.E. Bodway, "Circuit design and characterisation of transistors by means of 3 port scattering parameters", Microwave Jnl., Vol. 11, pp.55-63, 1968.

5. L. Besser, "Stability considerations of low noise transistor amplifiers with simultaneous noise and power match", IEEE Int. Microwave Symposium, pp.327-329, 1975.

6. G.D. Vendelin, "Feedback effects on the noise performance of GaAs MESFETS", IEEE Int. Microwave Symposium, pp.324-326, 1975.

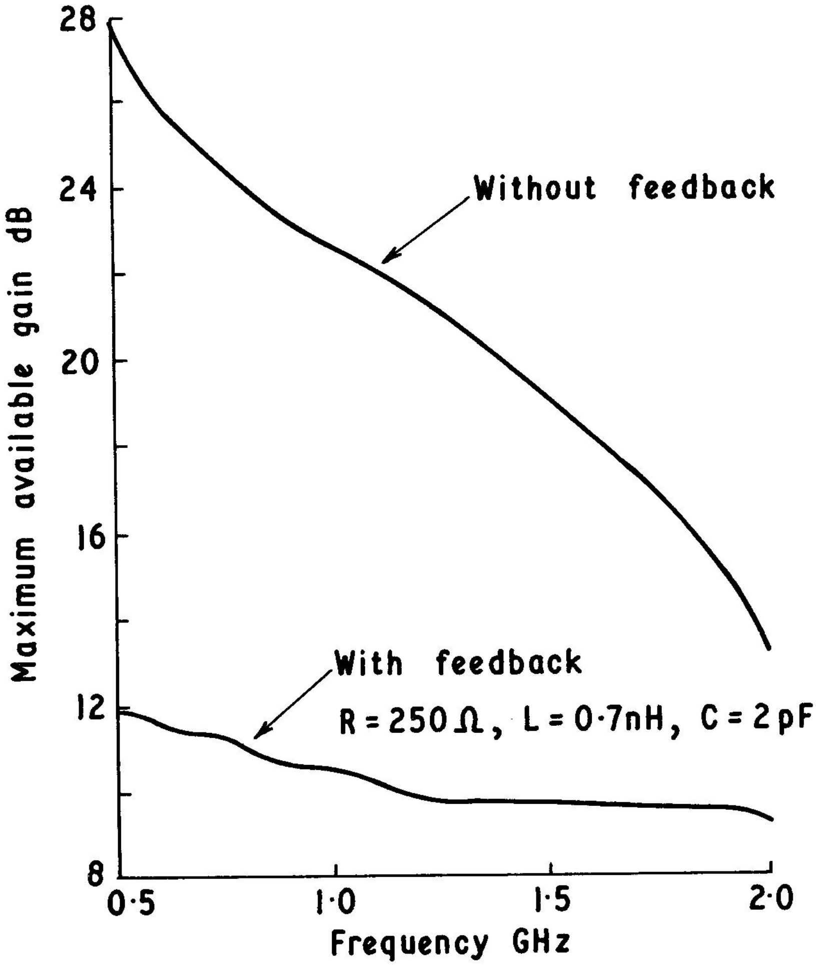

FIGURE 1. MAXIMUM AVAILABLE GAIN OF A MICROWAVE TRANSISTOR WITH AND WITHOUT FEEDBACK.

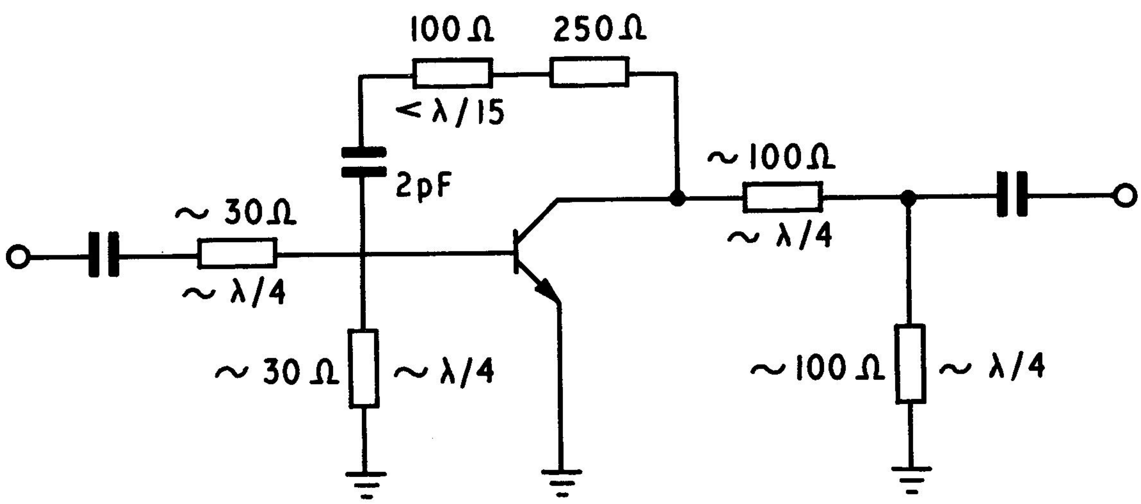

FIGURE 2. CIRCUIT OF THE FEEDBACK AMPLIFIER.

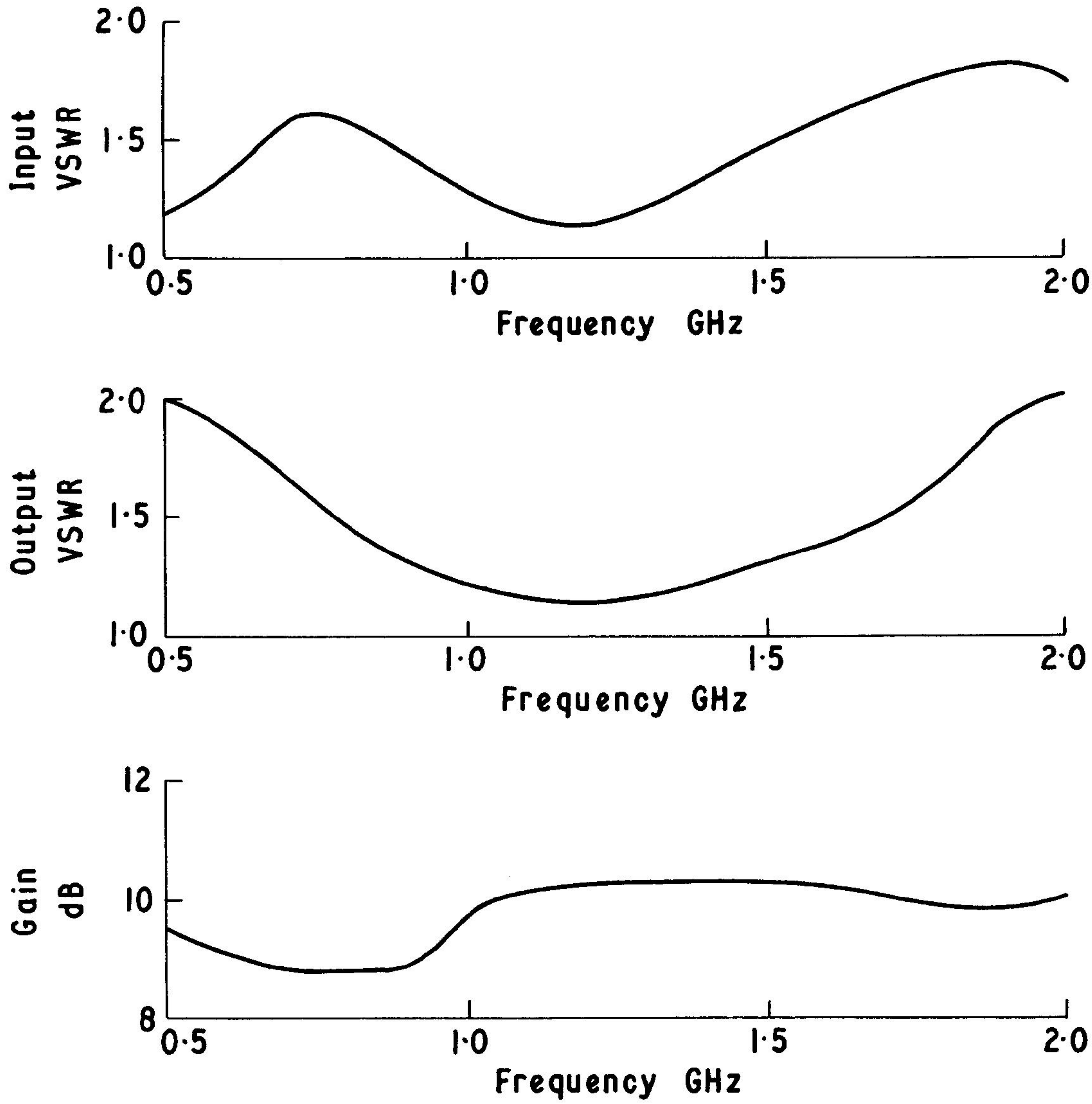

FIGURE 3. MEASURED PERFORMANCE OF THE FEEDBACK AMPLIFIER.