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Highly Linear Solid-State Power Amplifiers for Single Sideband via Satellite Applications

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Abstract

Highly linear FET amplifiers have been built to supplant conventional travelling wave tubes for application to C-band satellites serving spectrum efficient single sideband transmission. Detailed experimental results on various amplifier configurations are given.

Introduction

Companded single sideband has been shown to be an attractive method for increasing voice traffic communication capacity via satellites.[1] Calculations have shown it possible to accommodate 7800 low noise voice circuits per 36 MHz of bandwidth using 12-meter ground station antennas. However, to fully exploit the system advantages of this format, it is desirable to substitute linear FET amplifiers for the conventional TWT satellite channel amplifiers.

The purpose of this paper is to present experimental results characterizing laboratory amplifiers conceived with linearity and efficiency as prime objectives. Detailed results are given for a number of amplifier configurations which show promise for future satellite applications. These include amplifiers with output powers in the 5 to 15-watt range which meet performance objectives and constraints as follows:

a. Power-added efficiency greater than 25 percent.

b. The devices chosen from the Western Electric 131 family, which are space qualified and already in use aboard the TELSTAR 3 satellites.

c. Bias levels and circuit designs chosen to optimize linearity and output power.

d. 1 dB bandwidth should be at least 120 MHz.

e. Maximum variation in small-signal gain within the band shall be less than 0.3 dB in any 40 MHz.

f. Constructed utilizing microstrip transmission medium.

Device Specifications

Table I lists typical specifications for the 131 WECo GaAs FET family. It should be noted power-added efficiencies of greater than 40 percent can be achieved with the 131 AB devices.

TABLE I

Typical 131 Device Specifications

DEVICE	GATE LENGTH	POUT (dBm)	GAIN (dB)	Vds (Volts)	Ids (mA)
131 J	1mm	24	11.5	12	115
131 K	3mm	31.5	9.0	12	315
131 L	6mm	35	7.0	12	580
131 AB	8mm	36.2	7.0	12	770

Linearity Specification

The specification of carrier-to-intermodulation performance is generally quoted as C/IM at a given multicarrier output power. However, it is more convenient to specify C/IM versus single carrier saturated power output backoff when comparing amplifiers having differing power capabilities. A reasonable SSPA specification for twenty-four carriers is C/IM $\geq$ 75db·Hz at 2dB output backoff, varying linearly to C/IM $\geq$ 87db·Hz at 6dB output backoff.

Amplifier Configurations

The amplifier architecture shown in Figure 1 was constructed to demonstrate the performance of a 35dB gain, 10-watt amplifier at 4GHz. A photograph of the assembled unit is shown in Figure 2. The power transfer characteristics with single carrier and twenty-four carrier excitation are shown in Figure 3. The carrier-to-intermodulation performance with twenty-four carrier excitation is demonstrated in Figure 4. The 1dB bandwidth was 360 MHz.

A number of other amplifier configurations have also been assembled and tested; the results are summarized in Table II. Linearity and efficiency objectives have been met for all of the amplifiers.

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The automated test set used for measuring amplifier performance is described in a companion paper.[2]

Characterization

For each amplifier configuration, the following characteristics are considered in adjusting the amplifiers:

a. Single-tone output power versus input power.

b. Twenty-four carrier output power versus input power.

c. Twenty-four carrier C/IM versus output power.

d. Gain versus Frequency.

e. Drain and gate currents and efficiency as functions of output power.

Conclusions

Amplifier architectures yielding output powers in the 5 to 15-watt range having power-added efficiencies greater than 25 percent have been demonstrated. Considerable linearity improvement over TWTAs has been obtained.

References

[1] R. J. Brown, M. L. Guha, R. A. Hedinger, and M. L. Hoover, "Companded Single Sideband Satellite Transmission," Proceedings of 1982 GLOBECOM, December 1982.

[2] E. R. Carlson, "Automated Measurement System for Characterizing Power Amplifier Performance" Intl Microwave Symposium, IEEE MTT, June 1983.

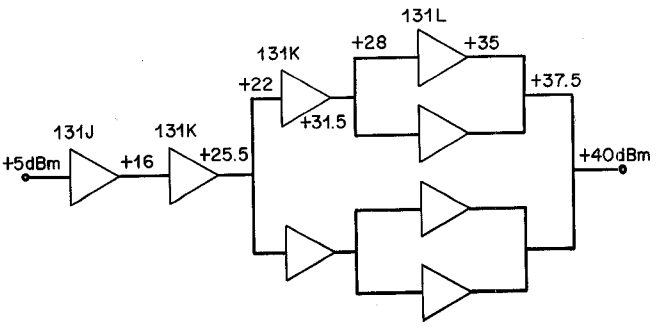

FIGURE 1: ARCHITECTURE OF THE 35 dB GAIN, 10 WATT, C-BAND AMPLIFIER.

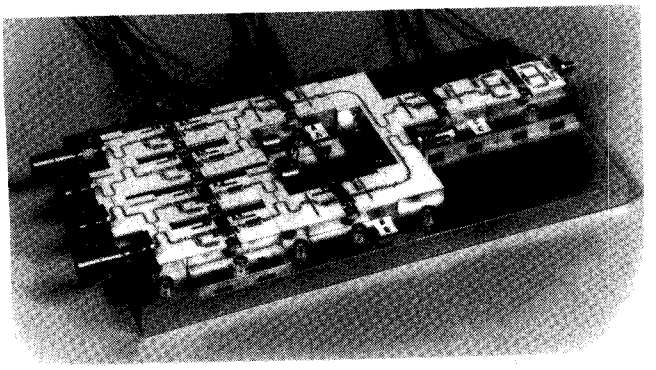

FIGURE 2: FINAL ASSEMBLY OF THE 35 dB GAIN, 10 WATT, C-BAND AMPLIFIER.

TABLE II

AMPLIFIER PERFORMANCE SUMMARY

Amplifier Configuration	Small Signal Gain (dB)	Psat (Watts)	C/IM (dB-Hz) Out 2dB	C/IM (dB-Hz) Put Back 6dB	C/IM (dB-Hz) Off	Small Signal 1dB BW (MHz)	Power Added Efficiency (%)
131 (J+K+K+AB)	32	5	76	89		400	30
131 (J+K+K+LPAIR)	32.6	6.6	75	87		310	30.5
131 (J+K+K+L+ABPAIR)	40	9.1	77	89		334	27.5
131 AB TRIO	7	13.2	74	85		410	28

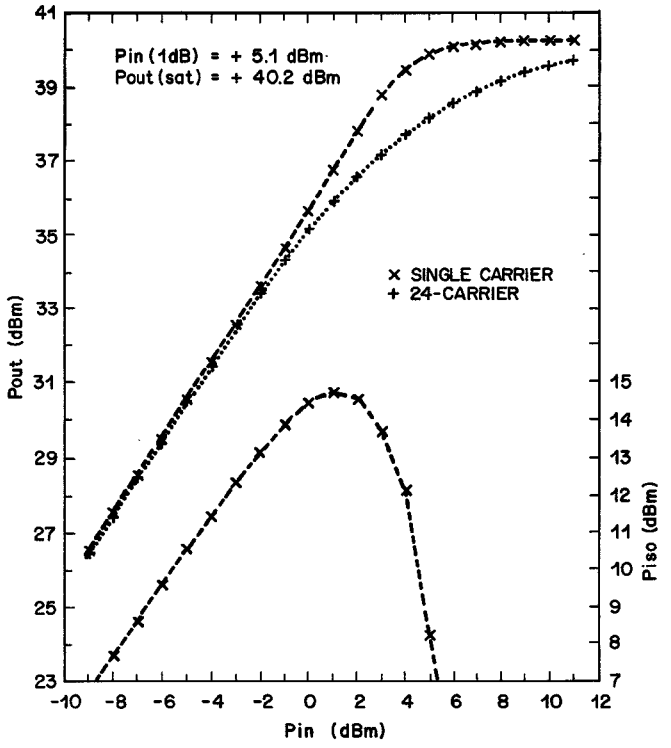

FIGURE 3: TRANSFER CHARACTERISTICS FOR THE AMPLIFIER OF FIGURE 2. SINGLE CARRIER ISOLATED PORT OUTPUT POWER (Piso) IS ALSO SHOWN.

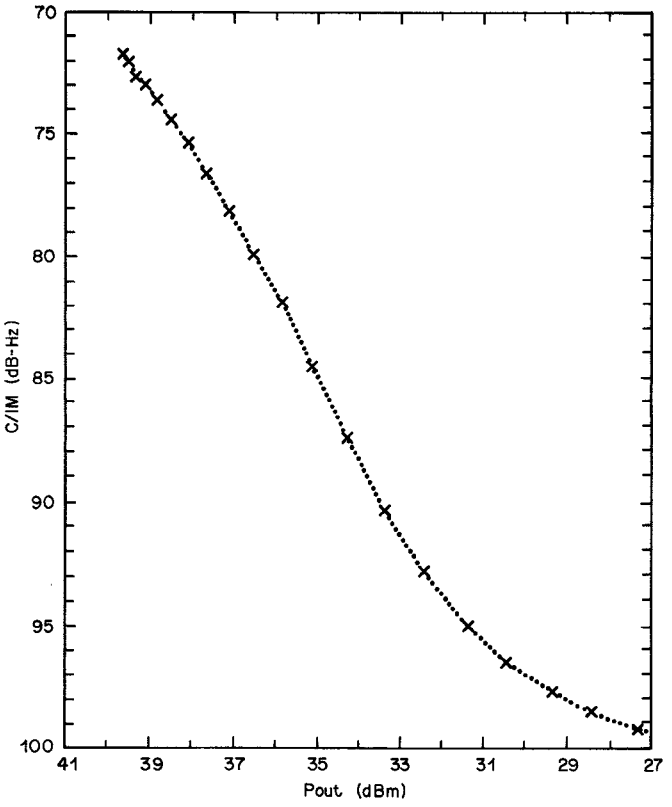

FIGURE 4: TWENTY-FOUR CARRIER TO INTERMODULATION DISTORTION VERSUS OUTPUT POWER AT 4 GHz.