A COMPACT 4GHz LINEARIZER FOR SPACE USE

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ABSTRACT

A compact and lightweight 4GHz linearizer for satellite TWTA has been developed by using MIC packages with chip devices. It consists of pre-amplifier, predistortion linearizer and limiting amplifier. It improves the noise power ratio for FM system by 3dB and required C/N for INTELSAT TDMA system by 4.5dB. The space environmental test and aging test are successfully performed.

I. INTRODUCTION

TWTs are most commonly used in satellite communication system for their large output power with a reasonable weight and power consumption. However, the amplitude and phase distortions near saturation degrades TWT performances. Predistortion technique can be used to compensate for these TWT nonlinear characteristics, and it will improve AM/AM and AM/PM conversion of TWT.

This paper describes the design, construction and performance of the linearizer for satellite TWT for future INTELSAT satellites operating both in SCPC and in TDMA modes. Space qualification tests including accelerated aging tests were also performed.

II. THE DESIGN OF LINEARIZER

There are several methods to compensate TWTA nonlinearity: feedforward(1),(2) and predistortion (3)-(7) are widely used. Feedforward compensation use two parallel paths one for TWT and the other for delay line. However, it requires two TWTs and a matching section, which will increase the weight and power consumption. On the other hand, predistortion circuit can be realized with low power amplifiers and several passive devices. Thus it can be compact, lightweight and low power consumption. Therefore, the linearizer of predistortion type has been developed for use in satellite transponders.

Figure 1 shows the block diagram of the 4GHz linearizer. It consists of 3 sections; a pre-amplifier, a predistortion linearizer and a limiting amplifier. In the pre-amplifier section, the input signal is amplified to enough level to drive the predistortion linearizer. Amplitude and phase distortion are generated in the predistortion linearizer section in accordance with the input power level to compensate the nonlinearity of the TWTA. The limiting amplifier section prevents the TWTA from overdrive operation and constant output power can be get above the saturation input level. Predistortion linearizer with limiting amplifier is called soft limit type linearizer, which can improve considerably Bit Error Rate(BER)(3).

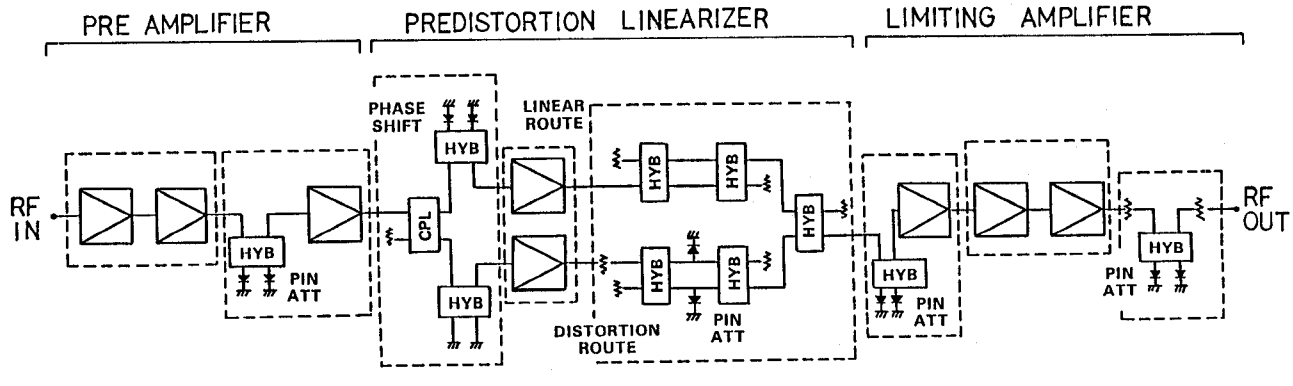

Figure 1 Block Diagram of 4GHz Linearizer

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In the linearizer section, input signal is divided into two signals, and they are fed to two different amplifiers with different signal levels. A Phase difference of about 180 degrees is provided between the two routes signal to obtain a desired distortion. Output signals of these amplifiers are combined by a hybrid, and the output of linearizer section is equal to vector sum of these signals.

The linearizer consists of 8 MIC packages as shown by dotted line in Figure 1. The first two packages form the pre-amplifier. The following three packages are the predistortion linearizer and the last three packages are the limiting amplifier.

The size of each package is 1 x 1/2 inch which includes MICs of 0.381mm alumina substrate and several chip devices such as GaAs FET's, PIN diodes and varactor diodes. Balanced type amplifiers, PIN attenuators and phase shifter are used to provide wide band performances from 3.3GHz to 4.7GHz to eliminate isolators. As a result, compact and lightweight linearizer is realized. Figure 2 shows the inner view of the balanced type amplifier.

The outline of the linearizer is shown in Figure 3. The RF section, a voltage regulator and bias circuits are installed in one housing. The dimensions of the linearizer is 160 mm in length, 110 mm in width and 23 mm in height and the weight is 461 g.

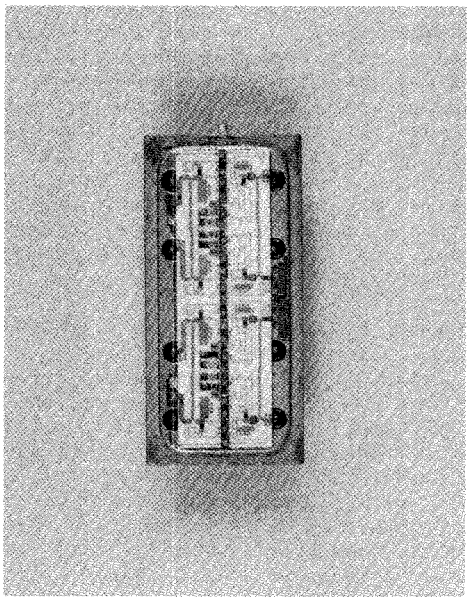

Figure 2 Inner View of Balanced Type Amplifier

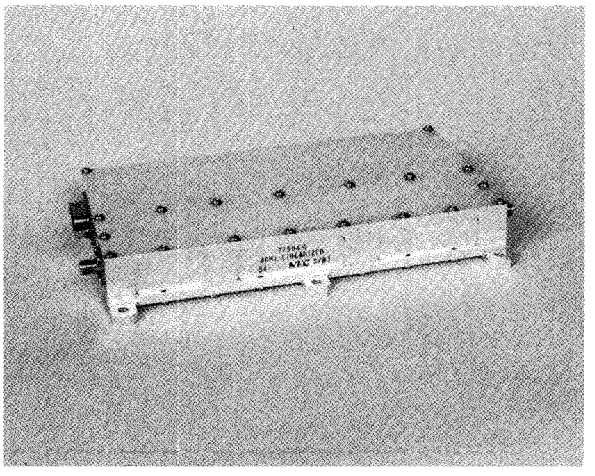

Figure 3 Outline of Linearizer

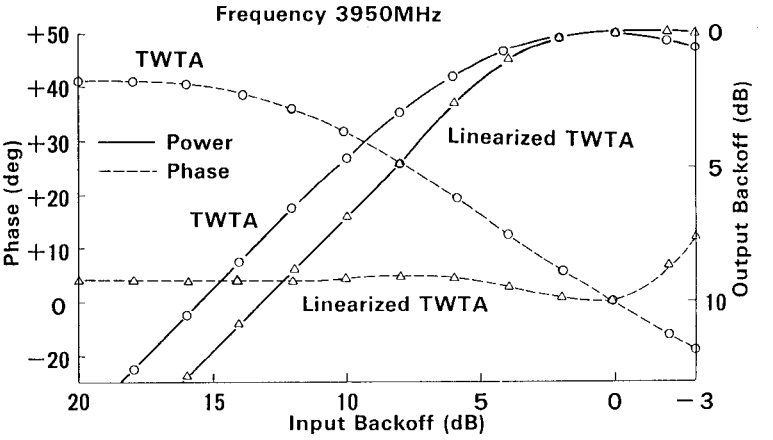

Figure 4 Input/Output Power and Phase Transfer Characteristics

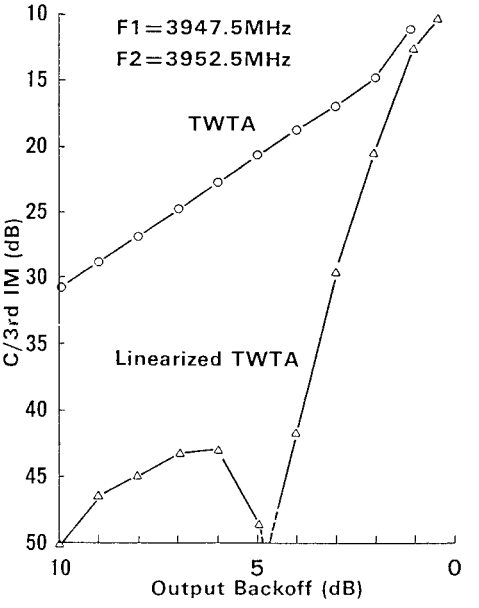

Figure 5 3rd Order Intermodulation

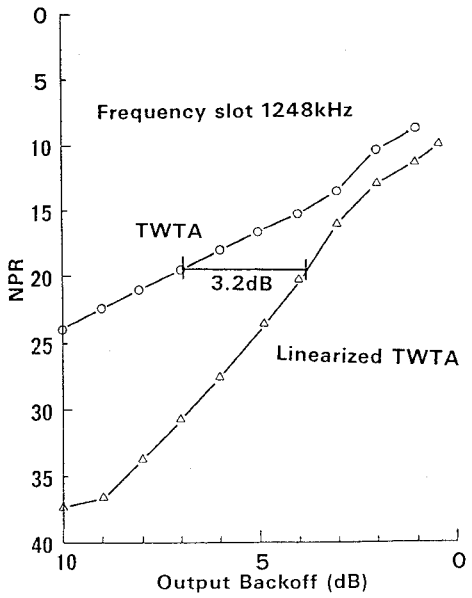

Figure 6 Noise Power Ratio

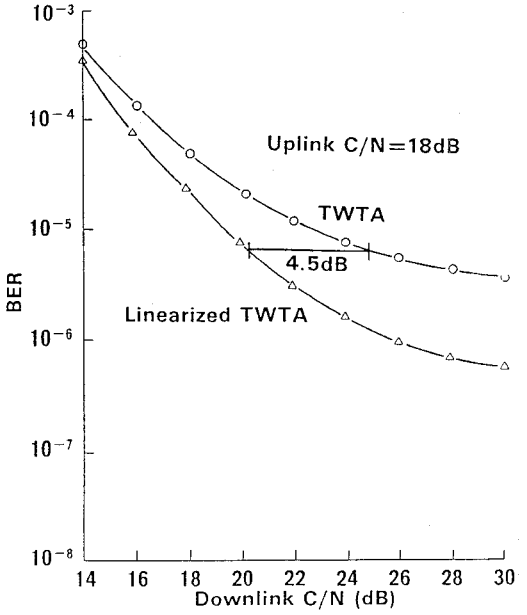

Figure 7 Bit Error Rate

III. PERFORMANCE OF LINEARIZED TWTA

The linearizer is adjustable externally controlling the bias voltage and current of the phase shifter and the PIN attenuators in order to compensate for nonlinearity of TWTA. The TWTA used in the experiment is Hughes model 249H TWT, which is similar to the onboard type TWT for INTELSAT-V. The linearizer is temperature compensated over the range from 10°C to 40°C by using the sensistors in the bias circuits. The input/output power and phase transfer characteristics of the TWTA and the linearized TWTA are shown in Figure 4. The power transfer characteristic of the linearized TWTA is almost linear up to saturation, and constant above saturation. The phase transfer characteristic of the linearized TWTA is suppressed to less than 5 degrees. The AM/PM conversion is reduced to 0.5deg/dB from 3.0deg/dB.

The 3rd order intermodulation of the TWTA and linearized TWTA are shown in Figure 5. The amount of improvement due to linearization is 23dB at 4dB output backoff (OBO).

The Noise Power Ratio (NPR) are shown in Figure 6. The linearized TWTA improves 11.6dB at 7dB OBO. Alternatively, the effective power is increased more than 3dB compared with the same NPR of TWTA 7dB OBO.

Figure 7 shows downlink C/N vs. Bit Error Rate (BER) of the TWTA and the linearized TWTA operating at 0dB OBO. NEC A1825B PSK MODEM was used in the experiment. The link conditions correspond to the INTELSAT-VI Hemi-to-Hemi SS-TDMA links. The required downlink CNR of the linearized TWTA is 4.5dB less than that of TWTA to achieve the identical BER at downlink C/N 25dB. Alternatively, the effective power will be increased by 4.5dB.

IV. SPACE QUALIFICATION TEST OF LINEARIZER

Qualification tests for the linearizer was performed. Before the qualification test, thermal cycling (from -40°C to 75°C, 5 cycles) and power aging (168 hours at 40°C) were performed.

The linearizer was subjected to sinusoidal sweep vibration and random vibration tests and thermal vacuum test of which the vibration levels and temperatures are those of an actual satellites. At the thermal vacuum test, thermal cycling were performed; ten cycles with power turning off over survival temperature range (from -40° C to 75°C), and ten cycles with power turning on over temperature range from 10°C to 40°C. During the qualification test the linearizer exhibits an excellent and stable performances.

The aging test were continued for 720 hours at 40°C of which is equivalent to 4320 hours at 23° C. The electrical performance were measured at 24 hours, 96 hours, 288 hours and 720 hours. The trend data is shown in Figure 9, which certify that the linearizer is stable.

V. CONCLUSION

A compact, lightweight and stable linearizer for satellite transponder has been developed using MIC packages. It is proved that the linearizer is stable against the environmental test such as vibration test, thermal vacuum test and aging test.

The linearizer improves the 3rd order IM, NPR and BER of the TWTA. It is exhibited that the effective power increased considerably in both SCPC and TDMA system.

The linearizer is adjustable for various types of TWT and solid state power amplifiers.

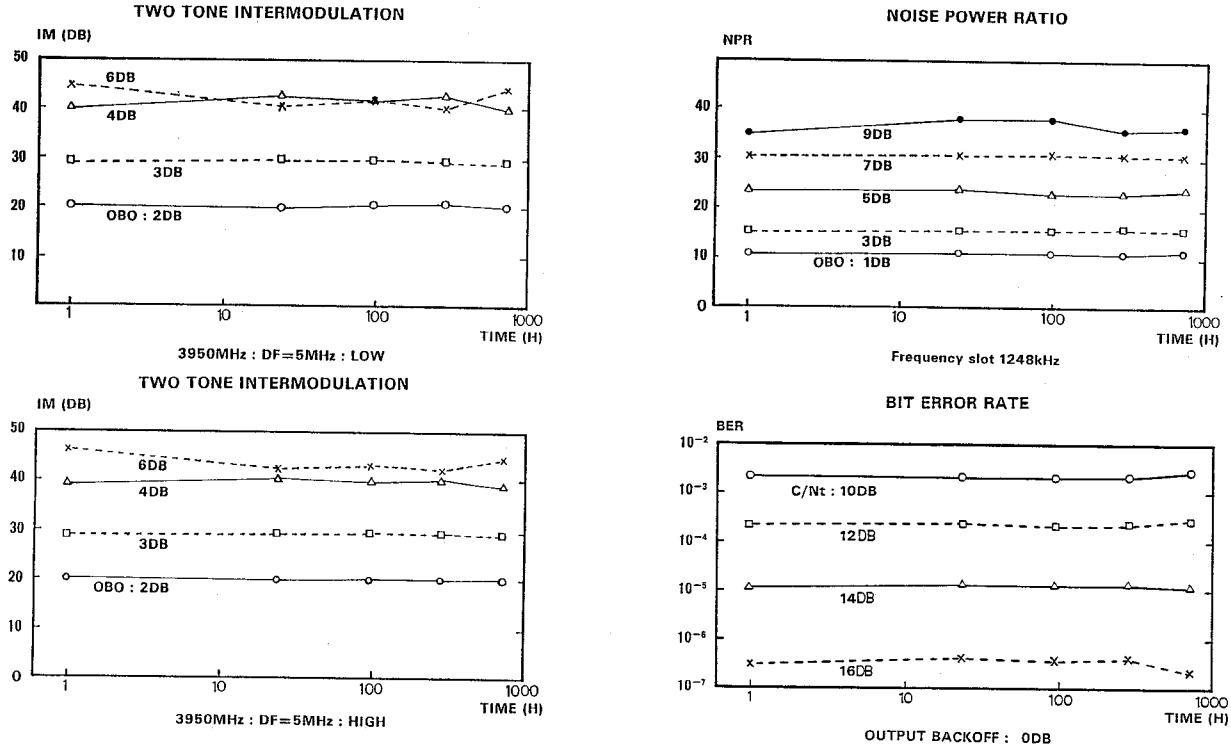

Figure 8 Trend Data of the Linearized TWTA

VI. ACKNOWLEDGMENT

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VII. REFERENCES

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