A Broadband Linearizer for Ka-Band Satellite Communication

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ABSTRACT

A compact, broadband linearizer has been developed at Space Systems Loral for Ka-Band communication satellite (20 GHz down link). The pre-distortion type linearizer is capable of providing up to 10 dB gain compensation and 80 degree phase compensation, and is suitable for broadband communication satellite.

INTRODUCTION

Commercial communication satellites are required to operate in multi-carrier environments carrying a large number of signals where intermodulation products from amplitude and phase nonlinearities of a TWT amplifier become a source of noise in the transmission band. To reduce these nonlinear effects, the operating power level of the TWTA must be sufficiently backed off relative to the saturation point, which leads to a much lower DC-to-RF conversion efficiency for the entire repeater.

A pre-distortion linearizer creates the inverse nonlinearirty of the TWTA in order to compensate for the amplifier distortion. The integrated linearizer and TWTA (LTWTA) is able to operate at higher power levels and maintain the same C/3IM and AM/PM specifications. In this paper, we present a compact, broadband pre-distortion linearizer developed in Space Systems Loral (SSL) for commercial satellite applications. The novel concept utilized in SSL linearizer made it possible for linearizer to work at lower power levels compared with other conventional design, which makes it suitable for satellite applications.

APPROACH

A block diagram of the SSL linearizer is shown in Fig. 1.

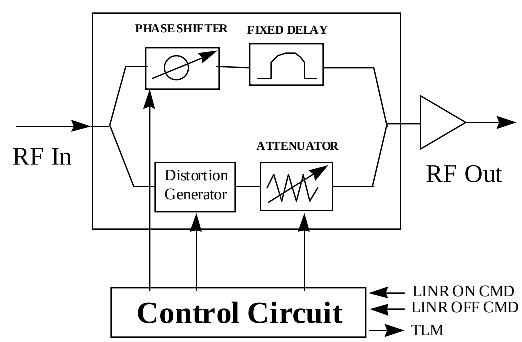

Fig. 1 Block Diagram of Linearizer

As shown in the diagram, the linearizer consists of a MIC linearizer bridge, a gain stage, and control circuit.

The linearizer bridge consists of two arms, linear phase shifting arm and nonlinear distortion arm. The linear arm consists of a phase shifter and a fixed delay line. The phase shifter is an analog design with 360 degrees phase range by summing two perpendicular signals whose magnitudes can be adjusted by two variable resistors. The fixed delay line equalizes the group delays between the linear and non-linear arms to minimize the dispersive effect over frequency. The nonlinear arm is comprised a Schottky diode distortion generator and a PIN diode attenuator. The distortion generator is a nonlinear circuit using Schottky diode to generate nonlinear gain and phase curves with respect to the input power levels. By applying a DC bias to the Schottky diodes in the distortion generator circuit, the SSL linearizer is working at lower power levels compared with conventional linearizer. The major advantage of this feature is that there is less heat dissipation in the circuit and less DC power is required for operation. The attenuator in the linearizer bridge equalizes the signal level between the linear and nonlinear arms.

The Libra Harmonic Balance Test Bench has been utilized for the simulation. The gain expansion and phase advance curves of the linearizer was designed such that they cancel the gain compression and phase lag of the TWTA over the desired power range and frequency range. In this case, the power level is -20 dBm to 0 dBm, and frequency range is 18~21 GHz.

To reduce the loss and the phase uncertainty of the interconnections, the entire linearizer bridge has been fabricated on one single 10 mil alumina substrate. Via holes have been utilized to provide proper grounding. The linearizer bridge substrate has a size of $0.1x0.45\ in^2$.

The SSL linearizer has two operation modes, active mode and by-pass mode. At active mode, linearizer generates required gain expansion and phase advance to match with TWTA. The gain expansion and phase advance curves can be adjusted by controlling the biases applied to the phase shifter and the attenuator. In addition, the curvature of gain expansion and phase advance curves can be adjusted by controlling the distortion generation bias. At linearizer by-pass mode, the attenuator in linearizer bridge will be set at its maximum attenuation value (>35 dB), hence the entire module acts like a linear circuit.

RESULTS

HP 8720C network analyzer has been employed to test the linearizer. The linearizer has been measured with a input power between -20 dBm and +1 dBm. Fig. 2 shows the gain and phase curves for 20 GHz, where the gain expansion and phase advance have been set at 5.7 dB and 40 degree respectively. By changing the bias voltage of phase shifter and attenuator, the linearizer is capable of providing up to 80 degree and 10 dB phase and gain compensation.

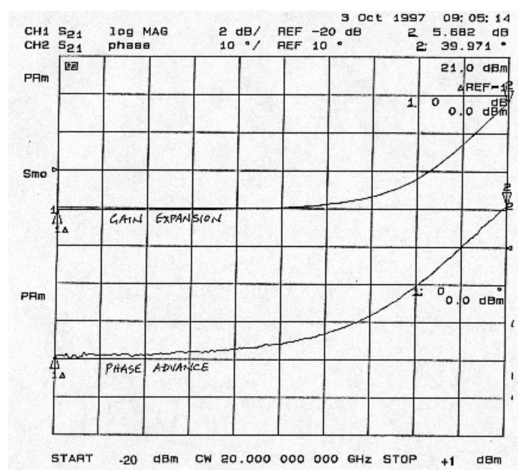

Fig. 2 Measured Gain Expansion and Phase Advance Curves.

The SSL linearizer is a broadband design. The S parameters with a -20 dBm input are shown in Fig. 3, where test has been conducted over the frequency range of 18-21 GHz. The gain variation is < 1.5 dB over the entire frequency band, while the return loss is better than 10 dB.

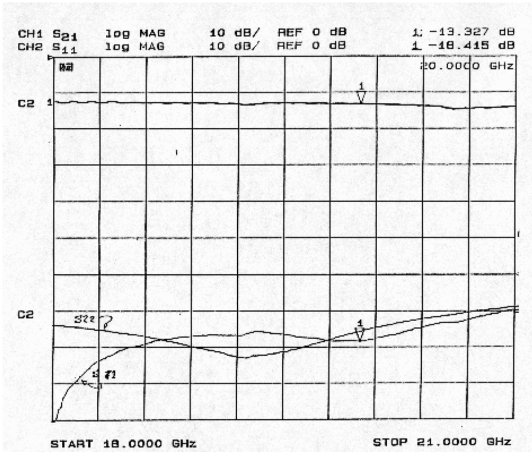

Fig. 3 Measured Gain and Return Loss Over Frequencies

Simulations have been conducted to predict integrated linearizer and TWT (LTWT) performance, where measured TWT and linearizer curves have been utilized. The TWT has about 7 dB gain compression and 35 degree phase lag. For this TWT, to avoid over compensate at lower power levels, the linearizer has been set at 5.5 dB gain expansion and 31 degree phase advance.

The power transfer curves of TWT alone and LTWT are shown in Fig. 4, where LTWT has a much better linearity compared with TWT alone. As a trade, the gain of LTWT is ~ 5.5 dB lower than TWT at lower power levels. As shown in the plot, the current linearizer does not have a limiter in the RF chain. Hence at higher than saturation power levels, LTWT performance is worse than TWT alone.

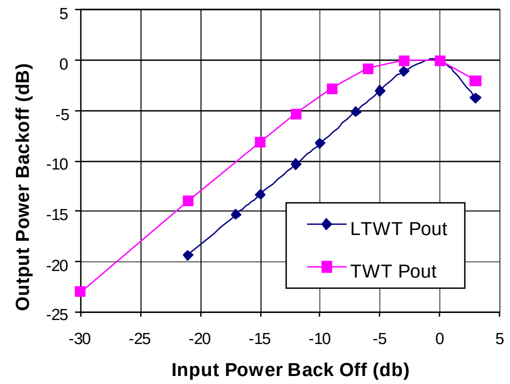

Fig. 4 Power Transfer Curves of TWT and LTWT.

Fig. 5 shows the phase variation of TWT and LTWT. The LTWT phase variation is < +/- 5 degree, while TWT alone has about 35 degree phase lag.

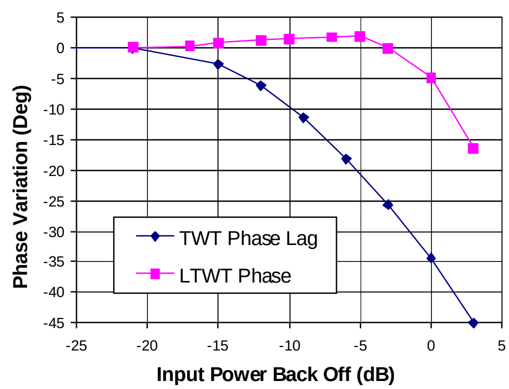

Fig. 5 Phase Variation of LTWT and TWT.

A simulation code for C/3IM has been developed in SSL for study of multi-carrier intermodulation product. The simulation code has been verified by the measured results at Ku-band and C-band. The simulation results of C/3IM for this 20 GHz LTWT and TWT alone are shown in Fig. 6.

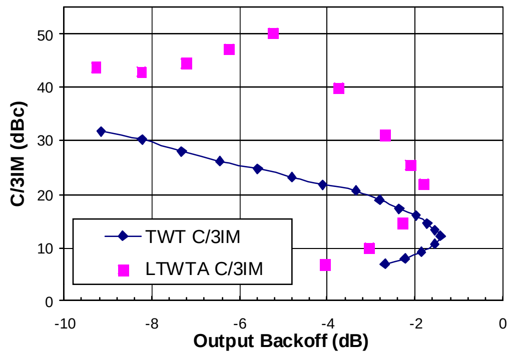

Fig. 6 C/3IM of LTWT and TWT

As shown in the plot, C/3IM of LTWT is significantly improved for power levels below saturation. C/3IM appears to have a peak around -5 dB output back off. Simulation indicates that, around this power levels, the fifth order intermodulation product is in the same power levels as the third order intermodulation product.

CONCLUSION

In conclusion, a compact , broadband linearizer has been developed at 20 GHz (18-21 GHz) with excellent performance for future Ka-band communication satellite systems, such as CyberStar, Local TV etc. programs.