A Novel Predistortion Linearizer Designed for Use in LMDS

A simple, cost effective, predistortion linearizer improves mimic amplifier non-linearities

By Todd Thornton and Dr. Larry Larson, Aethercomm, Inc. Denny Morgan, Remec, Inc.

A novel predistortion linearizer has been developed for the Local Multipoint Distribution Service (LMDS) transmit band of 27.5 to 28.35 GHz and improves the 3rd order carrier-to-intermod (C/I3) ratio up to 20 dBc for a 2-tone input. It offers an insertion loss of less than 10 dB with excellent input and output return loss from &#150 40 &#176 C to 60 &#176 C. This is the first predistortion linearizer presented for use with MIMIC amplifiers at the LMDS transmit band.

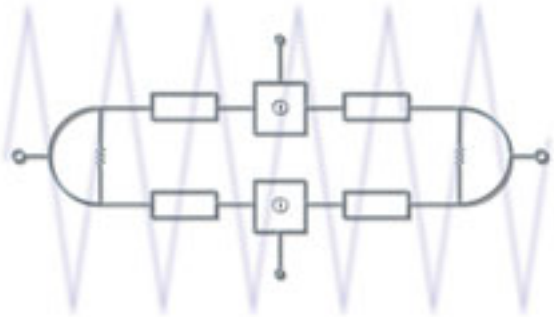

Figure 1. LMDS Predistortion Linearizer Schematic

Introduction

The Local Multipoint Distribution System uses Millimeterwave signals to transmit data, voice and video currently at 27.5 - 28.35, 29.1 - 29.25 and 31.0 - 31.3 GHz. The LMDS concept is cellular in nature, which means that the point to multipoint transmissions are based on multiple overlapping cells. The diameter of the cells is somewhere between 3 and 10 miles. LMDS will be used for two-way data transmission and it is hoped that the data transmission rates will exceed 1Gbps in the future.

The digital modulation formats for LMDS will include QPSK and possibly 64QAM. These digital modulation techniques, as well as analog television modulation, require extremely linear power amplification. The current and most cost effective method of power amplification for Millimeterwave modules requires the utilization of power amplifiers in MIMIC form. Current Millimeterwave MIMIC power amplifiers offered provide excellent output power (approximately 30 dBm or slightly greater) but the linearity can be marginal at lower temperatures. The MIMIC devices may not follow the classical 3:1 slope of the (C/I3) as a function of output power back off.

A current LMDS transmitter requirement presents a two-tone linearity specification of 30 dB (C/I3) over &#150 40 &#176 C to 60 &#176 C with a per tone output power of 20 dBm. The two-tone spacing is from 1 to 25 MHz. This linearity level cannot be met with existing GaAs MIMIC amplifiers without operating these devices

at excessive output-back-off (OBO), wasting dc power and incurring higher material cost. An elegant solution to the linearity requirement is to use a predistortion linearizer. A linearizer will allow the designer to use a smaller, more efficient MIMIC amplifier.

Predistortion Linearizer Concepts and Performance

The concept of linearization dates back to the 1930's and numerous results have been presented in the microwave frequency range for satellite communications. This paper chronicles the results of a predistortion linearizer used for a LMDS transmitter employing MIMIC amplifiers at 27.5 to 28.35 GHz. A simplified schematic diagram for this predistortion linearizer appears in Figure 1.

There are two main sources of nonlinearities in a Millimeterwave MIMIC amplifier, amplitude and phase nonlinearities. The intermodulation distortion arising from the phase nonlinearity is in quadrature to the amplitude nonlinearity. For the predistorter to be effective, it needs to be able to generate the inverse phase and amplitude transfer functions of the amplifier to be linearized. This problem is further complicated by the fact that not all Millimeterwave MIMIC amplifiers exhibit the same phase nonlinearity when driven close or into saturation. The predistortion linearizer must be able to generate a phase slope that can compensate for either type of phase response. The Millimeterwave predistortion linearizer described here can linearize either phase response with only slight circuit modifications.

The linearizer described in this article has a worst-case input return loss of 9 dB. It has a worst-case output return loss 10 dB. The cost of linearization is a reduction in the millimeterwave power gain. The predistorter has an insertion loss of about 9 dB when used to linearize the MIMIC amplifier that has the increasing phase function. The linearizer is controlled via an external voltage. The linearizer, when cascaded with the high power, positive phase response MIMIC, is operated between 2.0 and 3.0 Vdc for the best reduction in the (C/I3) ratio.

RMPA29000 Unlinearized and Linearized Device Performance

To show the benefits of linearization, a high performance MIMIC amplifier manufactured by Raytheon was selected. This MIMIC is the RMPA29000 and it was characterized with and without linearization. The device was characterized at three frequencies in the LMDS transmit band (27.500, 27.935 and 28.350 GHz) and at three temperatures (&#150 40, 25 and 60 &#176 C). The linearizer control voltage was manually adjusted for each different temperature. The ultimate goal of this characterization was to obtain the best (C/I3) ratio improvement at 20 dBm output power for each tone spaced at 10 MHz. Table 1, 2 and 3 show the performance of the MIMIC amplifier before and after linearization at the low end, the midband and the high end of the LMDS transmit band.

Lowband Tones: F1 = 27.500 GHz & F2 = 27.510 GHz

Lowband Tones: *F1 = 27.500 GHz & F2 = 27.510 GHz*

	Temp = -40° C			Temp = 25° C			Temp = 60° C		
Pin (dBm)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)
-7.00	21.23	-25.80	-30.87	17.00	-37.00	-45.30	15.27	-43.00	-47.80
-5.00	22.58	-24.00	-30.50	18.08	-34.00	-43.50	15.32	-39.00	-44.80
-3.00	23.96	-22.30	-28.00	18.59	-31.50	-40.00	17.39	-36.00	-40.67
-1.00	25.20	-20.00	-24.00	20.40	-29.00	-38.30	18.49	-34.00	-37.67
0.00	25.88	-18.00	-25.80	21.60	-28.50	-36.20	19.60	-31.00	-35.66
1.00	26.18	-16.00	-25.00	22.89	-24.00	-33.17	20.77	-28.00	-34.80
3.00	27.20	-18.11	-26.00	24.16	-23.00	-29.50	21.98	-26.00	-33.67
5.00	28.20	-17.80	-24.16	25.43	-21.80	-27.83	23.24	-24.00	-31.33
7.00	29.20	-16.00	-24.40	26.58	-21.30	-26.00	24.58	-22.00	-28.17
9.00	29.80	-16.00	-23.50	27.98	-20.00	-21.70	25.78	-21.00	-27.00
11.00	29.40	-17.00	-20.34	27.83	-19.30	-25.00	26.72	-20.00	-30.00
13.00	28.48	-14.80	-17.80	28.30	-17.30	-20.83	27.42	-18.30	-30.34
15.00	29.74	-13.00	-15.67	28.80	-15.80	-18.20	27.91	-18.00	-23.84
17.00	29.94	-11.80	-14.00	28.80	-14.00	-16.70	28.27	-16.70	-20.67
19.00	30.13	-10.80	-13.17	29.30	-12.80	-15.00	28.58	-14.80	-17.68
21.00	30.29	-10.30	-12.34	29.20	-12.30	-14.00	28.78	-13.80	-16.17

RMPA29000 C/I3 With and Without Linearization at LMDS Lowband
Table 1

Table 1. RMPA29000 (C/I3) With and Without Linearization at LMDS Low End of Band

Midband Tones: F1 = 27.935 GHz & F2 = 27.945 GHz

Midband Tones: *F1 = 27.935 GHz & F2 = 27.945 GHz*

	Temp = -40° C			Temp = 25° C			Temp = 60° C		
Pin (dBm)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)
-7.00	19.28	-30.00	-38.20	15.83	-38.00	-43.00	14.37	-42.00	-43.66
-5.00	20.43	-28.00	-35.30	16.98	-37.00	-42.00	15.58	-41.50	-38.50
-3.00	21.68	-26.30	-32.00	17.94	-34.00	-42.00	16.80	-38.00	-38.83
-1.00	22.97	-25.00	-29.70	18.10	-31.30	-42.00	17.89	-36.00	-36.16
0.00	24.23	-24.00	-27.80	20.40	-29.00	-44.00	18.79	-33.00	-35.84
1.00	25.40	-24.00	-28.50	21.47	-27.00	-38.00	19.92	-30.00	-37.00
3.00	26.32	-24.00	-27.00	22.70	-25.00	-34.80	21.12	-27.00	-37.00
5.00	27.09	-23.00	-29.67	23.83	-23.80	-34.80	22.22	-25.30	-34.18
7.00	27.86	-19.50	-29.00	24.88	-23.00	-36.30	23.62	-23.80	-30.17
9.00	28.02	-17.50	-27.50	25.88	-23.00	-33.20	24.81	-23.00	-24.84
11.00	28.29	-16.50	-23.70	26.70	-21.50	-28.50	25.78	-23.00	-20.67
13.00	28.48	-14.00	-21.30	27.33	-19.20	-21.83	26.52	-21.00	-18.00
15.00	28.64	-12.30	-20.00	27.85	-17.30	-18.83	27.03	-19.17	-16.30
17.00	28.79	-11.50	-19.50	28.20	-16.20	-16.16	27.37	-17.00	-14.50
19.00	28.90	-11.30	-18.70	28.50	-15.50	-16.17	27.63	-16.00	-13.33
21.00	29.02	-10.60	-17.80	28.32	-15.80	-14.83	27.80	-13.50	-12.84

RMPA29000 C/I3 With and Without Linearization at LMDS Midband
Table 2

Table 2. RMPA29000 (C/I3) With and Without Linearization at LMDS Midband

Highband Tones: F1 = 28.340 GHz & F2 = 28.350 GHz

Highband Tones: *F1 = 28.340 GHz & F2 = 28.350 GHz*

	Temp = -40° C			Temp = 25° C			Temp = 60° C		
Pin (dBm)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)	Pout (dBm)	Amp (C/I3) (dB)	Linearized (C/I3) (dB)
-7.00	17.08	-34.00	-37.80	15.74	-40.00	-43.00	13.83	-46.00	-39.00
-5.00	18.18	-32.00	-35.33	16.24	-39.00	-42.00	14.87	-44.00	-38.60
-3.00	19.38	-29.00	-30.17	17.29	-36.00	-42.00	15.88	-41.00	-38.60
-1.00	20.58	-28.00	-32.33	18.40	-33.00	-40.17	16.96	-38.00	-38.60
0.00	21.77	-26.00	-29.16	19.60	-30.00	-38.66	18.07	-35.00	-38.67
1.00	23.00	-25.50	-29.33	20.66	-29.00	-38.16	18.09	-32.00	-45.33
3.00	24.16	-25.50	-32.33	21.86	-26.30	-41.00	20.24	-29.00	-34.66
5.00	25.30	-24.80	-31.67	23.23	-24.80	-33.00	21.40	-27.00	-30.77
7.00	26.30	-24.00	-33.17	24.23	-23.50	-28.50	22.57	-25.00	-27.17
9.00	27.50	-24.00	-33.10	25.01	-23.00	-24.50	23.80	-23.80	-25.50
11.00	27.79	-22.50	-31.40	26.50	-22.80	-23.00	24.80	-23.00	-20.67
13.00	28.20	-20.00	-20.50	27.20	-21.87	-22.00	26.28	-22.00	-18.00
15.00	28.48	-18.00	-20.00	27.83	-20.00	-20.00	26.88	-21.50	-16.30
17.00	28.69	-16.00	-19.50	28.19	-18.30	-19.20	27.43	-19.80	-14.50
19.00	28.88	-13.00	-18.70	28.48	-15.80	-18.30	27.80	-18.00	-13.33
21.00	29.00	-12.10	-17.80	28.88	-14.30	-17.80	28.28	-16.00	-12.84

RMPA29000 C/I3 With and Without Linearization at LMDS Highband
Table 3

Table 3. RMPA29000 (C/I3) With and Without Linearization at LMDS High End of Band

A better indicator of the performance enhancement afforded by linearization is graphically displayed in Figures 2 through 4. Figure 2 displays the linearized and the unlinearized C/I3 performance of the MIMIC amplifier at 27.500 GHz with a second tone at 27.510 GHz at room temperature. The MIMIC amp, unlinearized, doesn't

meet the required linearity specification. When the device is cascaded with the predistortion linearizer the linearity specification is in compliance at all temperatures. The improvement at &#150 40 &#176 C at 20 dBm per tone output power is 7.87 dB. The improvement at 25 &#176 C is 9.3 dB. The improvement at 60 &#176 C is 6.83 dB.

Figure 3 displays the linearized and the unlinearized C/I3 performance of the MIMIC amplifier at 27.935 GHz with a second tone at 27.945 GHz at room temperature. The unlinearized MIMIC is compliant only at 60 &#176 C. When the device is cascaded with the predistortion linearizer the linearity spec is in compliance at all temperatures. The improvement at &#150 40 &#176 C at 20 dBm output power per tone is 7.3 dB. The improvement at 25 &#176 C is 15 dB. The improvement at 60 &#176 C is 7.0 dB.

Figures 3 displays the linearized and the unlinearized C/I3 performance of the MIMIC amplifier at 28.35 GHz with a second tone at 28.34 GHz at room temperature. The unlinearized MIMIC amplifier doesn't meet the required linearity specification. When the device is cascaded with the predistortion linearizer, the linearity requirement is compliant at all temperatures. The improvement at &#150 40 &#176 C at 20 dBm output power per tone is 4.33 dB. The improvement at 25 &#176 C is 11.16 dB. The improvement at 60 &#176 C is 5.66 dB.

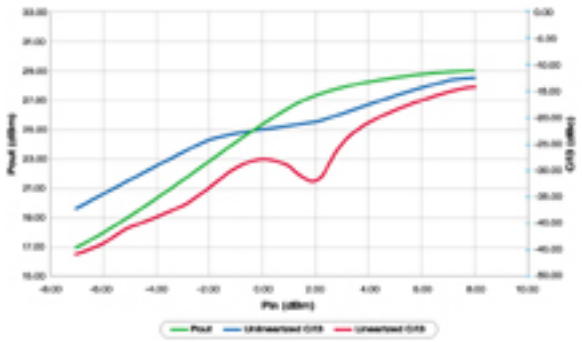

Figure 2. RMPA29000 C/I3 Performance @ 25 &#176 C - LMDS Low End

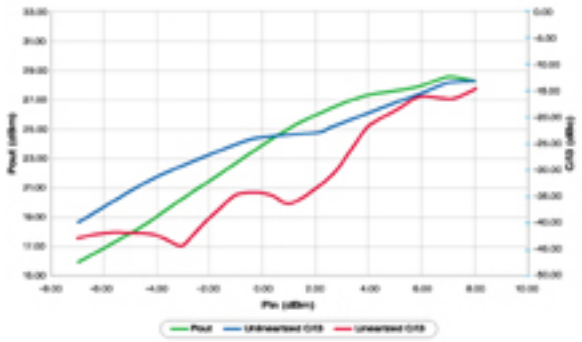

Figure 3. RMPA29000 C/I3 Performance @ 25 C - LMDS Midband

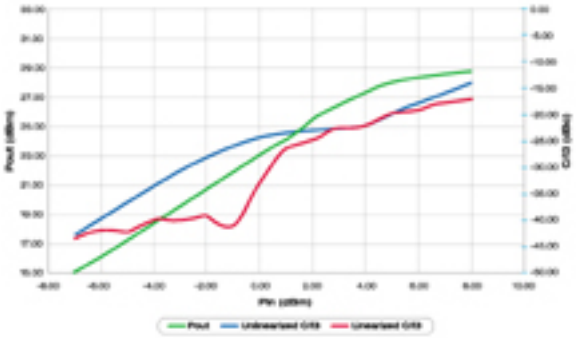

Figure 4. RMPA29000 C/I3 Performance @ 25 &#176 C - LMDS High End

The data presented above graphically depicts the virtues of linearization. At a specific output power, the C/I3 ratio is improved over a bandwidth of 850 MHz and over a temperature range of 100 &#176 C. The control voltage applied to the linearizer is changed only slightly as a function of temperature. The predistortion linearizer is easily adaptable to linearize any MIMIC amp at different output power levels.

The predistortion linearizer described in this article offers consistently better C/I3 ratios at practically all output power levels. For the graphical data in Figure 1, the linearized C/I3 ratio is always better than the unlinearized C/I3 ratio. For the midband LMDS frequency range a similar result is obtained. Figure 2 shows that the linearized C/I3 ratio is always better than the unlinearized case. For the high end of the LMDS band, linearization is also consistently better than the device by itself. Figure 3 shows that linearization always affords a better C/I3 ratio than the device itself, though the device itself is equal to the linearization case from an output power level of 24 to 25 dBm. Looking at the data in its totality, the linearized MIMIC amplifier performs better than if it were used alone without linearization.

Conclusions

A novel predistortion linearizer has been designed for the LMDS transmit band of 27.5 to 28.35 GHz. It has been demonstrated that this linearizer can be used with a millimeterwave MIMIC amplifier that has a marginal C/I3 ratio for a rated output power of 20 dBm and bring this device into compliance. This linearizer can improve a MIMIC amplifier's C/I3 ratio by up to 20 dBc. This linearizer has a VSWR of less than 2:1 for both its input and output ports. The linearizer operates from &#150 40 &#176 C to 60 &#176 C with a simple control voltage input. This linearizer can compensate for either a leading or lagging phase shift for specific input drive conditions. The device's total material cost is less than 10 US dollars in quantities of 100.

Denny Morgan is a Senior Vice President of Remec, Inc. He is co-founder of Remec. Denny is a graduate of Massachusetts Institute of Technology.
Dr. Larry Larson is the Chief Technical Officer of Aethercomm, Inc. Dr. Larson is also a professor at UC, San Diego. He is a fellow in the IEEE. Dr. Larson received his Ph.D. from UCLA.
Todd Thornton is President and Chief Executive Officer of Aethercomm, Inc. Todd did his graduate work at the Georgia Institute of Technology.

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