Miniaturized Transmitter in Digital Modulation System with Non-constant Envelope for VHF Band

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Abstract— In this paper, compact transmitter included power amplifier linearization in digital modulation with non-constant envelope for VHF band using cartesian feedback loop is presented. The digital modulation(QPSK/16-QAM/64-QAM) signal is non-constant envelope with constant peak to average power ratio. Digital modulation signal used when linearizing PA is 64-QAM, 70 ksps symbol rate, 0.35 of roll-off factor, and 7.5 dB PAPR. We used the Mitsubishi's Silicon power module, RA60H1317M1A, as a results, obtained an Adjacent Channel Power Ratio(ACPR) of less than −72 dBc, Error Vector Magnitude (EVM) of 2.8% at +39 dBm in VHF band. This technique is utilized to achieve miniaturization of transmitter with high linearity.

1. INTRODUCTION

Today, digital modulation rather than analog has been primarily used in wireless communication. The primary reason is to transfer more data without error since information to be transmitted via the wireless communication has changed from voice to data. However, QPSK and QAMs which is higher order digital modulation for large amounts of data transmission have a non-constant envelope due to the modulation using both of phase and amplitude. In addition, non-constant envelope signal has a high PAPR, the signal give a heavy load on the power amplifier of the transmitter. That is, to achieve high linearity, power amplifier should be as much as or more back-off than PAPR. Therefore, power amplifier should be designed with power higher than the specified transmit power [1].

In using a power amplifier, a high linearity and efficiency transmitter configuration through a small back-off is relatively simple. In general, to obtain high linearity of the power amplifier without the use of excessively high power amplifier, linearization techniques are used. These techniques allow that the output power of the power amplifier is used close to its saturated power while maintaining high linearity. In addition, a highly efficient performance of the power amplifier can be achieved. That is, a highly linear and efficient power amplifier is capable of reducing the size of the transmitter [2, 3].

Cartesian feedback which is one of linearization techniques adopt quadrature modulator as up-converter. A coupled signal of the power amplifier output in quadrature transmitter is demodulated in quadrature phase, and the demodulated signal is fed back to pre-distort baseband I/Q signal for the linearization [2–4].

In this paper, in order to obtain a high linearity of a power amplifier, we implemented a miniature transmitter using the cartesian feedback linearization technique. The implemented transmitter has high linearity at the maximum output power which is backoff power less than PAPR of non-constant envelope digital modulation signals such as QPSK, 16QAM, 64QAM and this is the same result with the signals of different bandwidths.

2. THE CONFIGURATION OF THE MINIATURIZED TRANSMITTER

Figure 1 shows a block diagram of a transmitter for digital modulation in the VHF band, which can transmit more than a 8 W average power. The transmitter consists of quadrature modulator/demodulator, driving amplifier, and power amplifier. CML Microcircuits' CMX998 is used as a quadrature modulator, which is up-converts baseband analog In-phase and Quadrature signals to the VHF band. In addition, it has a demodulator for cartesian feedback. To output more than a 8 W average power, up-converted signal is amplified by the amplifier which is used BEREX's BIF7 as a driving amplifier, and Mitsubishi's RA60H1317M1A as a power amplifier.

3. THE MEASURED PERFORMANCE OF THE TRANSMITTER

Figure 2 shows test results of RA60H1317M1A biased $Vd = 12\,\text{V}$ and $Vg = 4.5\,\text{V}$ with a 1-tone and digital modulation signal. As shown in the Figure 2, gain and 1 dB gain compression point ($P_{1\,\text{dB,out}}$) of power amplifier are +39 dB and +43.6 dBm respectively. Also, ACLR(Adjacent Channel Leakage Ratio) of the power amplifier is −41 dBc at +39 dBm of average power with digital

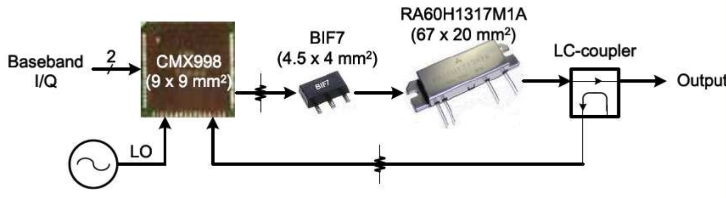
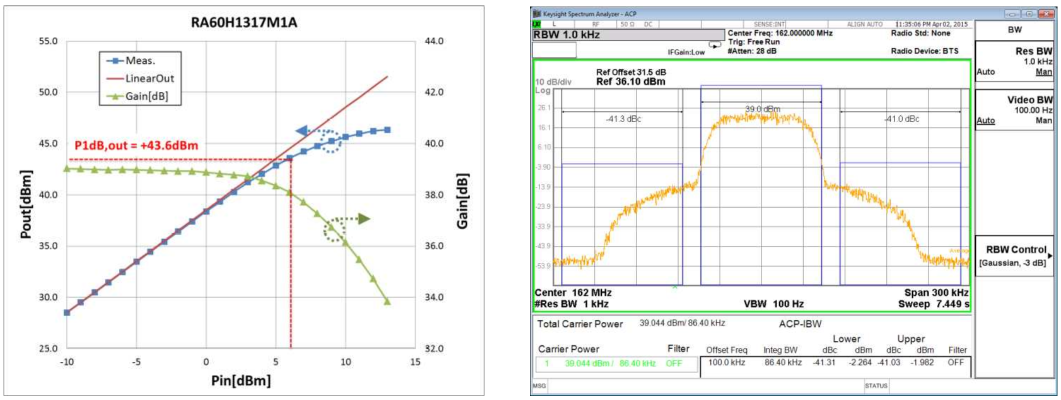


Figure 1: The configuration of the miniaturized transmitter.



(a) (b)

Figure 2: The characteristic of the power amplifier(RA60H1317M1A). (a) Gain and $P_{1\,\mathrm{dB}}$. (b) ACLR.

modulation signal, which is 64-QAM, 70 ksps symbol rate, 0.35 of roll-off factor, and 7.5 dB PAPR.

To verify the performance of the implemented transmitter for the digital modulation, the test environment was configured as shown in Figure 3. Digital modulation signals which are QPSK, 16QAM, and 64QAM are generated by signal generator. Digital filter has 0.35 of roll-off factor, and Null to Null bandwidth of digital modulated signals is 25 kHz, 50 kHz, and 100 kHz. By this test configuration, we measured the maximum output power of the transmitter corresponding to each signal. Also, we observed ACLR and EVM at the maximum power.

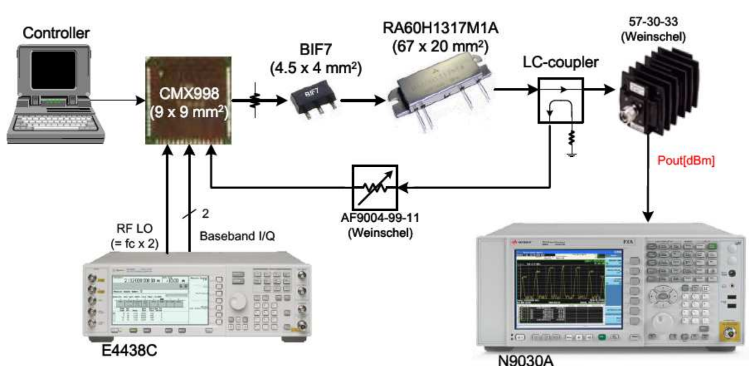


Figure 3: Test configuration of the transmitter for digital modulation.

As one of the results, Figure 4 shows results using 64QAM, 100 kHz bandwidth signal. The signal's PAPR is 7.5 dB. With this signal, we obtained an Adjacent Channel Power Ratio(ACPR) of less than −72 dBc, Error Vector Magnitude(EVM) of 2.8% at +39 dBm which is the maximum output power of the transmitter.

Generally, maximum output power of the transmitter is backed off as much as or more than PAPR from $P_{1\,\mathrm{dB,out}}$ of the power amplifier [4]. This is expressed by Equation (1).

$$P_{\mathrm{OUT,MAX}}\,[\mathrm{dBm}] = P_{1\,\mathrm{dB,OUT}}\,[\mathrm{dBm}] - PAPR\,[\mathrm{dB}] + K\,[\mathrm{dB}] \tag{1}$$

where, K represents the degree of improvement compared to the PAPR back-off, $P_{1\,\mathrm{dB,out}}$ denotes

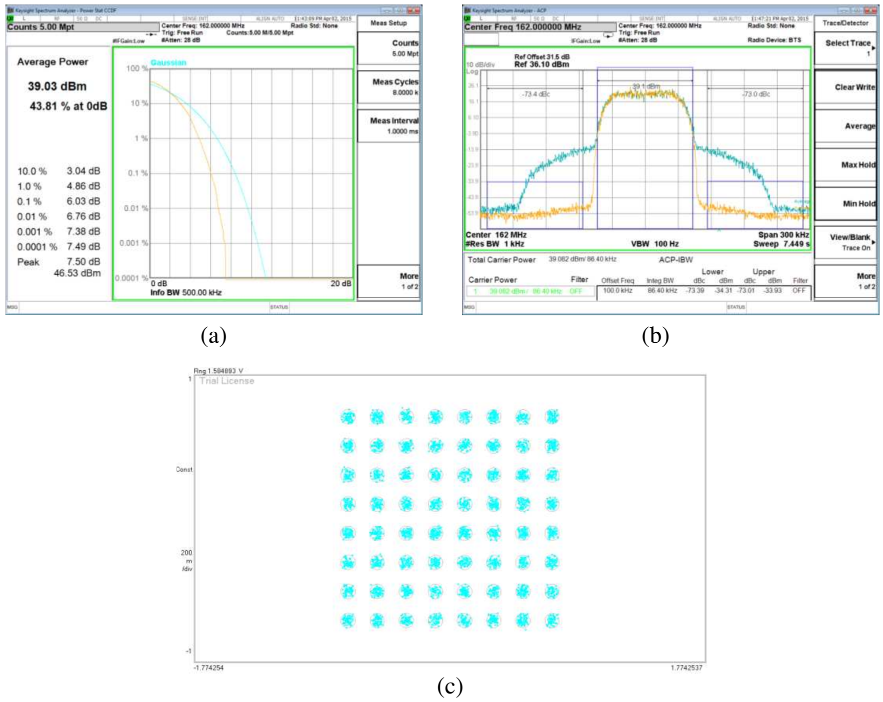


Figure 4: Measured performance of the transmitter with 64-QAM, 100 kHz bandwidth signal. (a) CCDF. (b) ACLR before and after linearization. (c) EVM (= 2.8%) on constellation.

maximum output power available in transmitter, and $P_{1\,\mathrm{dB,out}}$ means 1dB Gain compression point at output of power amplifier.

Table 1 summarizes the measured results of the implemented transmitter for the various bandwidth and digital modulation. As shown in the Table 1, the maximum transmitter output power of this study are results of backoff smaller than PAPR from the $P_{1\,\mathrm{dB,out}}$. That is, The amount of the back-off is 2.6 to 3.9 dB smaller than the PAPR. Also, we can be seen that ACLR is less than −75 dBc, EVM is less than 1% corresponding to the digital modulation (QPSK/16QAM/64QAM) signal with 25 kHz and 50 kHz bandwidth. Even for 100 kHz bandwidth signal, ACLR is less than −72 dBc, and this represents high linearity. However, EVM is slightly higher than different bandwidth as 2.8 to 4.4%. This is because the bandwidth of the baseband block is designed narrower than 100 kHz.

Table 1: Performance of the transmitter to the different bandwidth and modulation.

Bandwidth (Null to Null)	Modulation	PAPR [dB]	Max. output Power [dBm]	**K [dB]**	ACLR [dB]	EVM [%]
25 kHz	QPSK	5.0	+42.5	**3.9**	< −78.0	0.43
	16QAM	6.8	+40.5	**3.7**	< −77.5	0.32
	64QAM	7.4	+39.5	**3.3**	< −78.0	0.28
50 kHz	QPSK	5.3	+41.0	**2.7**	< −77.0	0.68
	16QAM	6.8	+40.0	**3.2**	< −76.5	0.32
	64QAM	7.5	+39.0	**2.9**	< −77.0	0.42
100 kHz	QPSK	5.2	+41.0	**2.6**	< −70.2	4.40
	16QAM	6.9	+40.0	**3.3**	< −70.7	3.30
	64QAM	7.5	+39.0	**2.9**	< −719	2.80

4. CONCLUSION

A transmitter using the linearization technique of the power amplifier for non-constant envelope, such as QPSK, 16QAM, and 64QAM digital modulation signal, is implemented. The transmitter performance shows wide bandwidth, high linearity compared to previous result[5]. Also, Back-off is smaller than PAPR was used to make output power close to $P_{1\,\mathrm{dB}}$ of its power amplifier in VHF band, while maintaining high linearity.

We obtained the maximum output power of the transmitter up to +39 (= 8 W) to +42.5 dBm (= 17.8 W) through power amplifier with $P_{1\,\mathrm{dB,out}}$ of +43.6 dBm (= 22.9 W), while achieving high linearity as ACLR of −70 dBc or less. The maximum output power are results of backoff smaller than PAPR of non-constant envelope signal from the $P_{1\,\mathrm{dB,out}}$. The amount of the back-off is 2.6 to 3.9 dB smaller than the PAPR. Output power is close to $P_{1\,\mathrm{dB,out}}$ of power amplifier as much as that.

In the future, we are going to modify the baseband block to improve EVM of transmitter for the signals of 100 kHz bandwidth

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