A Modified Predistortion Technique for Mixer Linearization

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***Abstract* – The backed-off method of input power level is generally used for design of highly linear mixer. In this paper, a predistortive mixer design method which has a predistortor in front of the mixer is proposed to compensate the nonlinear characteristics of the mixer. The proposed method improves C/I ratio of the mixer by 22dB (@P_o= -20dBm/tone), with two tones of RF at 1852.5 MHz, 1857.5MHz and LO at 2015MHz.**

Ⅰ. INTRODUCTION

Mixer performs up or down conversion of frequency by using nonlinearity of mixer with LO (Local oscillator) signal. So mixer is one of important elements in homodyne and heterodyne transceiver[1].

Mixer is designed using GaAs MESFET or Schottky diode which have basically nonlinearity, when LO signal enters mixer. On frequency up- and down-conversion processing, intermodulation distortion signals and many spurious signals unnecessarily occur besides up- and down-converted frequencies. And these intermodulation distortion signals and spurious signals cause increase of conversion loss (decrease of conversion gain) and distortion of converted signals[2].

Also intermodulation distortion signals can be a jamming noise which influences an adjacent channel and an element limiting quality of whole communication system. Especially when the frequencies of RF signals are f_1, f_2 and the frequency of LO signal is f_L ($f_L > f_1, f_2$), the frequencies of the 4th order intermodulation distortion are $f_L-2f_2+f_1$, $f_L-2f_1+f_2$[3]. These intermodulation distortion signals are located very near to RF signals and can't be eleminated by an ordinary filter, and the 4th order intermodulation signals have a big influence on neighboring signals. So, carrier to the 4th order intermodulation signal ratio is used to represent the distortion rate. This is called $(C/I)_{4th}$ ratio (Carrier to the 4th order intermodulation ratio)[4].

In order to improve this $(C/I)_{4th}$ ratio, in a passive mixer, backed-off method of input signal or harmonic balanced method have been used to find an optimum operation condition. In an active mixer, the method which finds optimum operating voltage of GaAs MESFET has been used. But the methods presented above have many difficulties and defects. This paper proposes the predistortive mixer design method has a predistortor in front of the mixer to reduce intermodulation signals.

Because a transceiver needs very linear mixer in mobile base station, the mixer is operated with backed-off input signal level and high LO level. Therefore, LO signal is leaked from the LO port of the mixer along with very small up/down converted signals and intermodulation signals. Occasionally the level of leaked LO signal is higher than the level of up- or down-converted signals. Hence rejection of leakage signals is critical. And a high level of LO signal may reduce RF system stability. But if slightly backed-off method and predistortive mixer are used, the above problem can be resolved.

Ⅱ. A DESIGN OF PREDISTORTIVE MIXER

Fig.1 shows input and output spectrum of general down-conversion mixer, and the output spectrum shows intermodulation distortion signals besides down-converted signals due to nonlinearity of the mixer. Fig.2 shows the spectrum and the block diagram of predistortive mixer proposed in this paper. The operation principle is as followings.

When RF input signals are down-converted, input RF signals are divided by Wilkinson divider. Parts of divided RF signals enter ALC (Automatic Level Controller) maintaining constant output signal level despite changing of RF input signal level, thus constant output signal of ALC enters ISG (Intermodulation Signal Generator) generating distortion signals.

After RF signals and predistortion signals enter mixer, these signals are converted by mixing with LO (Local Oscillator) signal. Especially at the IF port, intermodulation signals occured by RF signals and the predistortion signals are also down- converted, and these signals have the same frequency. Hence, if the amplitude and the phase of predistortion signals entering RF port are adjusted appropriately, intermodulation distortion signals accompanied by down converting RF signals will be

minimized.

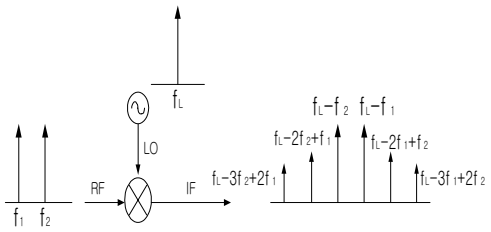
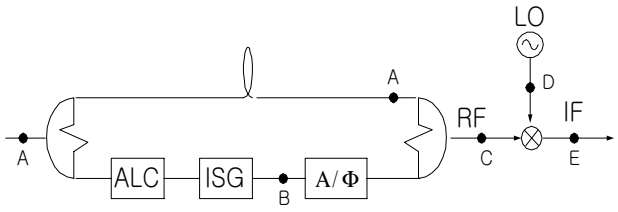


Fig.1 Input and Output Spectrum of Mixer(@$f_L > f_1, f_2$)



ALC : Automatic level controller
ISG : Intermodulation Signal Generator
A/Φ : Attenuator & Phase Shifter

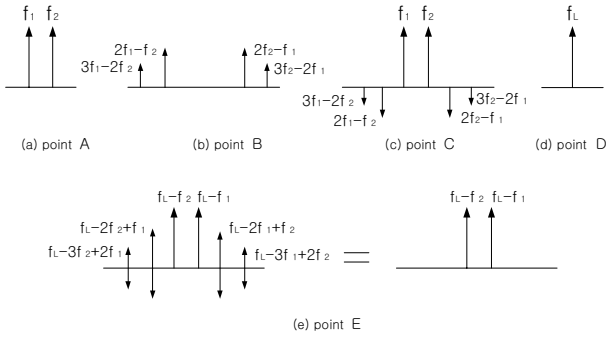


Fig. 2 Block diagram and spectrum of predistortive mixer

A slightly backed-off input level of base station mixer reduces very much the 6th intermodulation components but reduces a little the 4th intermodulation components. So if a predistortive mixer can reduce the 4th intermodulation components effectively, predistortive mixer design method is more effective than RF signal back-off method having many problems[5].

In this paper, the predistortive mixer design method is presented. The principle of ALC circuit is the following. First, RF signals which entered ALC pass through attenuator and amplifier. And then the output signals of ALC are divided into final output port and a signal deteor for converting RF signal into DC voltage(V_d). That is, after comparing detecting voltage V_d with reference voltage V_{ref}, if the detected voltage is higher than V_{ref} (if the output level is higher then reference level), the attenuator increases attenuation and if the detected voltage V_d is lower than reference voltage V_{ref} (if the output level is lower then reference level), the attenuator decreases attenuation to maintain output power constant.

By this process, the detected voltage V_d becomes the same with reference voltage V_{ref} and the output power level of ALC is kept constant. Output signals of ALC enter ISG (Intermodulation Signal Generator) generating distortion signals.

ISG consists of MMIC amlplifier, variable attenuator and variable phase shifter and Fig. 3 shows ISG circuit. Generally MMIC amplifer can obtain signal amplification by biasing current and (or) voltage presented by a manufacturer, also nonlinearty of MMIC can be changable by changing bias condition.

In this case, operation voltage and power level at which the 3rd intermodulation signals level is at least 20dB higher than the 5th intermodulation signals level are investigated.

One part of divided input signal pass through MMIC amplifier and attenuator attenuating the amplified signals and distortion signals. The other divided signals pass through variable phase shifter changing the phase of input signals.

At this time, as adjusting variable attenuator to maintain the same level of other path signals and phase shifter to be opposite phase of other path signals, only the 3rd order intermodulation signals are presented in output port of combiner. Fig. 4 shows output characteristics of ISG.

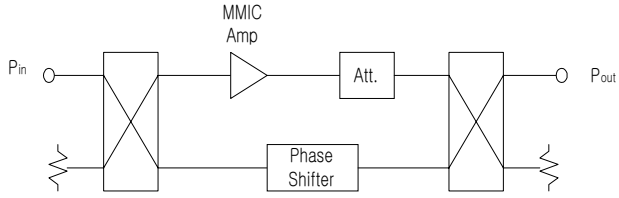


Fig. 3 Block diagram of the intermodulation signal generator (ISG)

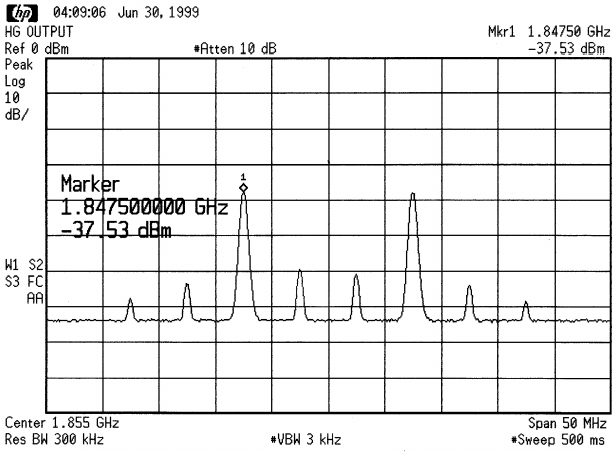


Fig. 4 Output characteristics of the intermodulation signal generator (ISG)

Ⅲ. IMPLEMENTATION AND EXPERIMENTS

To show better performance of predistortive mixer, the intermodulation distortion characteristics of typical mixer and predistortive mixer are examined.

Frequencies of 2-tone carrier signals are 1852.5MHz, 1857.5MHz and frequency of LO signal is 2015MHz. Mixer and LO used in this experiment are LRMS-30J and JTOS-2200P of Mini-circuits. The measured conversion loss of mixer is 8.5 dB, and P_1dB is -7.2dBm.

ALC output of predistortive circuit is designed to be -4.3dBm/tone, and the 3rd order intermodulation signal occured in ISG is -37.53dBm/tone. As this time, the 5th order intermodulation signal level is -63.6dBm/tone, so the difference between the 3rd order intermodulation signal and the 5th order intermodulation is 26dB. The MMIC amplifier used in this experiment is MSA-0386 of HP. The diodes used in variable phase shifter and attenuator for the purpose of changing phase and amplitude are 1T362 of Sony and HSMP-4810 of HP.

Fig. 5 shows output characteristics of typical mixer and predistortive mixer when IF output is -20dBm/tone. The $(C/I)_{4th}$ ratio are each 38.66dBc and 60.62dBc, 22 dB is improved by using predistortive circuit.

Fig. 6 shows the improvement by comparing intermodulation distortion characteristics of a typical mixer with that of a predistortive mixer when IF output level changes from -14dBm/tone to -20dBm/tone, the improvement is 17.15~21.96dB. As output level of mixer gets higher, improvement effect gets lower. This means that as RF level of the mixer is higher, imbalance property appears.

As this time, imbalance presents that although the level of each 4th intermodulation signal of mixer is different, the level of each predistortion 4th signal is almost the same.

So when observing Fig. 6, if the output level of diode maintain less than -20dBm/tone, (C/I) of predistortive mixer can be less than 60dBc. Fig. 7 is a photograph of the predistortive mixer.

Ⅳ. CONCLUSION

In this paper, a design method of predistortive mixer is proposed to decrease intermodulation signals occuring in up- or down-conversion of multi-carrier signals or CDMA signal.

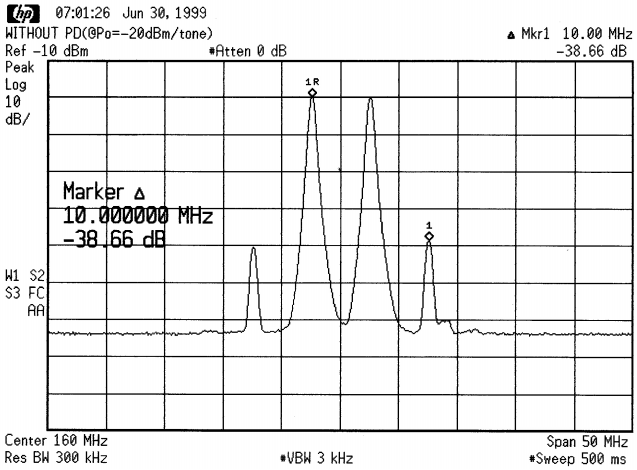
If predistortive circuit having the opposite characteristics of the distortion characteristics of the mixer is attached in front of mixer, (C/I) ratio could be obviously improved in the output port of mixer.

A conventional base station mixer is operated with high level of LO and intentional back-off of RF or IF signal level for frequency conversion, but these methods cause problems reducing RF system stability according to using high level LO signal and need high leakage signals rejection filter due to excessive back-off.

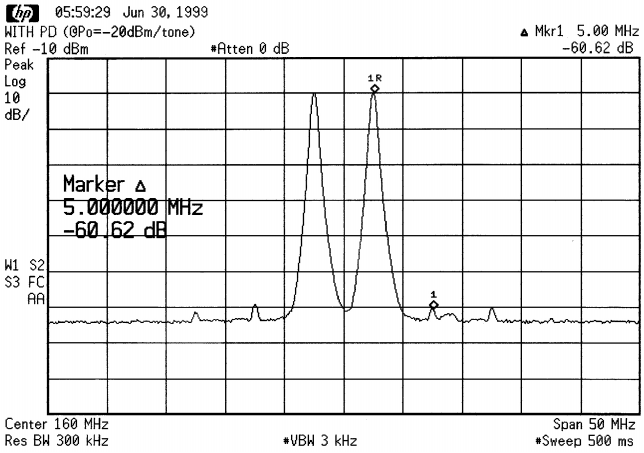
But the predistortive mixer design method proposed in this paper can be used in mobile communication base station by slight back-off and by appropriate removal of the 4th order intermodulation distortion signal.

Although this predistortive mixer design method was applied in a passive mixer in this paper, this design method can also be applied in an active mixer design.

When this method is applied in frequency up or down converting circuit in base station, the performance of whole communication system will be obviously improved.



(a)



(b)

Fig. 5 (a) Output characteristics of a typical mixer ($@P_O$=-20dBm/tone)
(b) Output characteristics of a predistortive mixer ($@P_O$=-20dBm/tone)

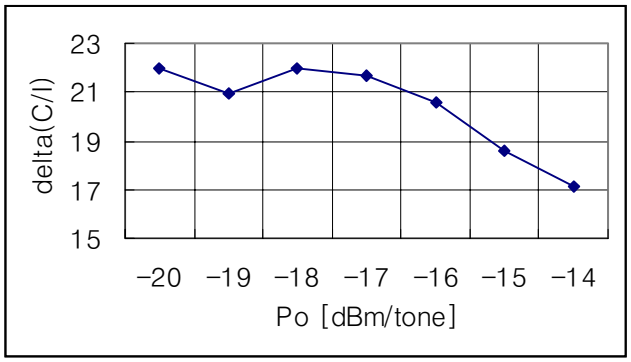


Fig. 6 The improvement of intermodulation distortion

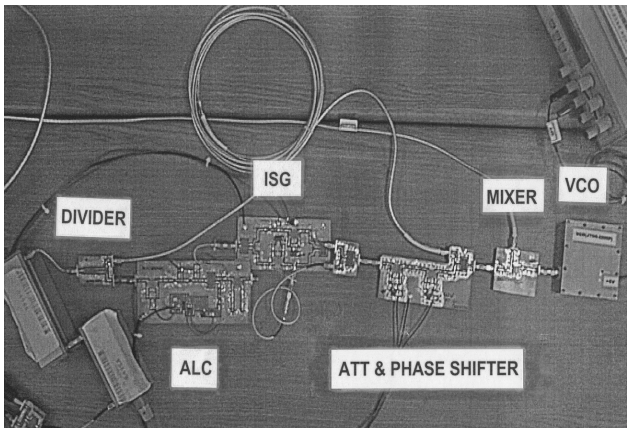


Fig. 7 Photograph of the predistortive mixer circuit

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