A Feedforward Power Amplifier with Loops that can reduce RX Band Noise Signals as well as Intermodulation Signals

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Abstract – **In this paper, a new power amplifier is proposed for reduction of amplified RX band noise signals as well as TX band intermodulation distortion signals using feedforward technique. The proposed power amplifier, contains two loops-TX band intermodulation distortion signals cancellation loop and RX band noise signals cancellation loop, can provide duplexer with low TX path insertion loss for various wireless communication systems due to choice of loose RX attenuation characteristic. The proposed amplifier is implemented for IMT-2000 base station frequency band. Experimental results represent that the cancellation performance of intermodulation distortion signals and RX band noise signals are more than 31dB and 21dB, respectively.**

Ⅰ. INTRODUCTION

In various RF systems, it is important that the isolation characteristic of desired and undesired signals. The price of RF front-end section is influenced by the isolation characteristic between TX and RX path mainly. In the case of TX power amplifier, intermodulation distortion signals present additionally when TX signals are amplified. As a result of efforts on cancellation of intermodulation distortion signals, several types of power amplifier with intermodulation distortion signals cancellation loop have been developed[1][2].

However, amplified RX band noise signals on amplifying TX band signals, as shown in Fig. 1, are transferred to duplexer without reduction and some of them are soaked into RX path. Thus, RX SNR is decreased. Also, to improve the isolation characteristic to RX path, the RX band attenuation of TX band pass filter should be increased. It increases the TX path insertion loss naturally. Thus, to compensate for the increased TX path insertion loss, output power of TX amplifier should be increased. As the output power increases, the cost for implementing the power amplifier is also increased with the same rate. Finally, to improve the isolation characteristic, it should be followed that the significant rising of the system prices.

In this paper, we propose the new feedforward power amplifier with two loops, TX band intermodulation distortion signals cancellation loop and RX band noise signals cancellation loop, to reduce the intermodulation distortion signals and to improve the RX rejection characteristic. By employing the RX band cancellation loop additionally, RX band noise signals can be reduced in TX output significantly.

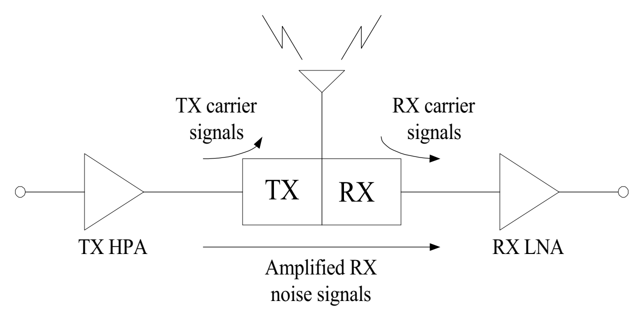

Fig. 1. Signals flow in full duplexing communication system

Ⅱ. THEORY

The block diagram of the proposed power amplifier is shown in Fig. 2(a). The principle of operation of the proposed amplifier is well illustrated with four-tone spectrum which represented in Fig. 2(b)~(h).

Input signals, as shown in Fig. 2(b), consist of two-tone TX signals and RX noise signals, it is divided by coupler 1 into main path and sub-path. When signals injected into main path go through the main amplifier, intermodulation distortion signals are generated at the main amplifier output (point A shown in Fig. 2(a)). It is by directional coupler that a part of signals is extracted at output section of the main amplifier. Divided signals are injected into substracter in TX intermodulation distortion signals cancellation loop and RX band pass filter in RX noises cancellation loop through Wilkinson divider, respectively. Other signals injected into substracter are shown in Fig. 2(d), and only

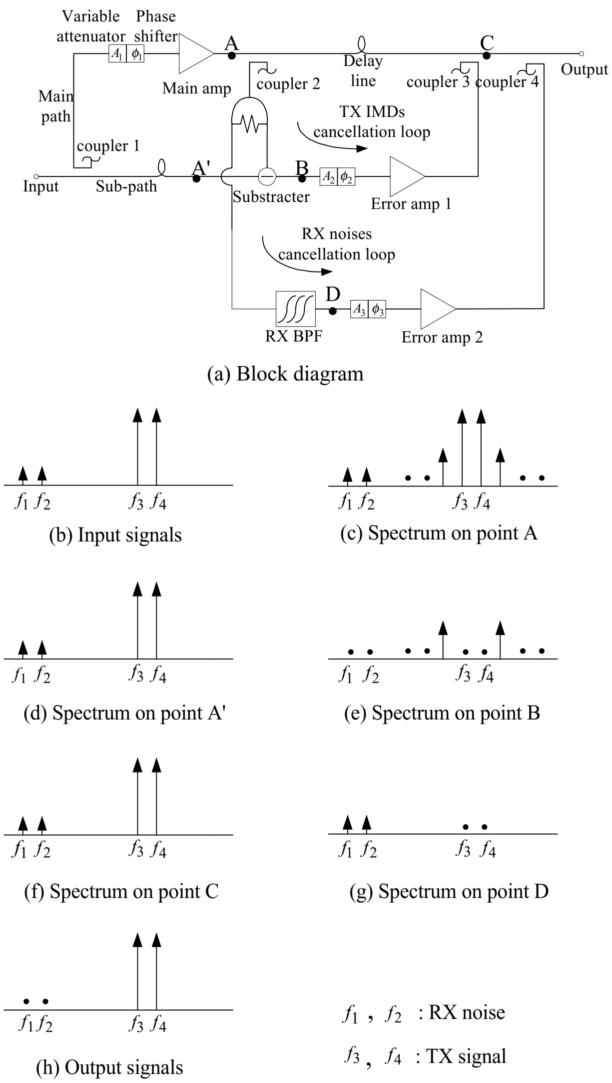

Fig. 2. The proposed power amplifier

intermodulation signals present at substracter output (point B), as shown in Fig. 2(e). Intermodulation distortion signals in substracter output are adjusted to satisfy conditions (1) and (2) by variable attenuator (A_2), phase shifter(ϕ_2) and error amplifier 1.

(1) The magnitude of the signals which injected into coupler 3 through TX intermodulation distortion signals cancellation loop must have the same magnitude as intermodulation distortion signals which injected through delay line.
(2) The phase difference between signals which injected into coupler 3 through TX distortion signals cancellation loop and intermodulation distortion signals which injected through delay line is 180°.

Under the situation to satisfy conditions (1) and (2), intermodulation distortion signals are eliminated at output section of the coupler 3(point C), as shown in Fig. 2(f). However, RX noise signals are not still eliminated. This phenomena are caused by limited frequency property of devices in TX intermodulation distortion cancellation loop. These results were used to the conventional power amplifier. Thus, amplified RX noise signals are transferred to duplexer without reduction, it decreases the system performance.

In this paper, we employed additional cancellation loop to eliminate RX noise signals. RX band pass filter is contained to extract the only RX noise signals in this loop, and spectrum of the RX band pass filter output (point D) is shown in Fig. 2(g). Similarly to the operation of TX intermodulation distortion signals cancellation loop, RX noise signals through RX band pass filter are adjusted by variable attenuator(A_3), phase shifter(ϕ_3) and error amplifier 2. Fig. 2(h) shows final output signals that are eliminated RX noise signals. The delay time of RX band noise signals in passing through RX band pass filter, variable attenuator(A_3), phase shifter(ϕ_3) and error amplifier 2 is compensated with main path delay line. So additional delay line doesn't need to cancel RX wideband noise signals.

Ⅲ. IMPLEMENTATION & EXPERIMENTS

The implemented main amplifier consists of an ERA-5SM manufactured by Mini-Circuit and a XHL-21336 and a MRF-19030 manufactured by Motorola, it has 57dB gain and 0.3dB flatness over IMT-2000 frequency band. Error amplifier 1 in TX intermodulation distortion signals cancellation loop consists of two ERA-5SMs and a XHL-21336, error amplifier 2 in RX noise signals cancellation loop consists of four ERA-5SMs. Total gains of error amplifier 1 and 2 are 64dB and 68dB, respectively. Because noise signals level of RX band is much lower than that of TX band signals, error amplifier 2 can be realized with small signal transistors.

The 30dB directional coupler manufactured by KMW(KDCNRW30-32-01) and the 10dB directional coupler manufactured by ANAREN(1A1305-10) are used for linearization loop. For substraction circuit, Wilkinson coupler is used.

Variable phase shifter is a reflection type hybrid phase shifter using varactor diode [3]. The phase shifter has about 120 degrees of the adjustable phase control range. The variable attenuator is a low phase shifter attenuator using pin diode, attenuation range of the variable attenuator is about 30dB under 1 degree of phase deviation[4].

The RX band pass filter using λ/4 coupling line technique of insertion loss method is implemented for extraction of RX noise signals [5][6]. The implemented RX band pass filter has 1.8dB insertion loss over RX frequency band and 24dB attenuation characteristic over TX frequency band.

When output power of main amplifier is 36.4dBm/tone, two-tone intermodulation distortion characteristic of main amplifier is shown in fig. 3. Fig. 3 shows that the intermodulation distortion characteristic of main amplifier is 33.5dBc. The spectrum of substracter output is shown in fig. 4, it shows that rejection characteristic of main carrier signals is 50.7dBc. As shown in fig. 5, the cancellation performance of intermodulation distortion signals is more than 31dB.

To show the rejection characteristic of RX band noise signals effectively, HP-8753D vector network analyzer (VNA) is used for measurement. Because RX band noise signals are much smaller than TX band signals, in this paper, TX band pass filter is attached to VNA and then connected to the proposed feedforward power amplifier. Input signal waveform is shown in fig. 6. The characteristic of only RX band noise signals cancellation loop is shown in fig. 7. The characteristic of feedforward HPA with RX band noise signals cancellation loop is shown in fig. 8, it shows that the cancellation performance of RX band noise signals is more than 21dB.

Ⅳ. CONCLUSIONS

To reduce the RX band noises, a new feedforward TX power amplifier with RX band noise signals cancellation loop is proposed. The power amplifier is implemented for IMT-2000 base station frequency band. By employing the RX band noises cancellation loop, the rejection performance of RX band noise signals is improved more than 21dB for RX full band of IMT-2000. Also, TX intermodulation distortion signals are reduced more than 31dB due to feedforward linearization technique. Thus, RX noises that soaked into RX path decreases and RX isolation characteristic toward TX for duplexer can be looser than the cases of conventional power amplifier. Therefore, we can expect the reduction of costs and occupied volume for implementing the duplexer with high TX to RX isolation characteristic. In addition, we can reduce the output power of the amplifier due to duplexer with low TX path insertion loss.

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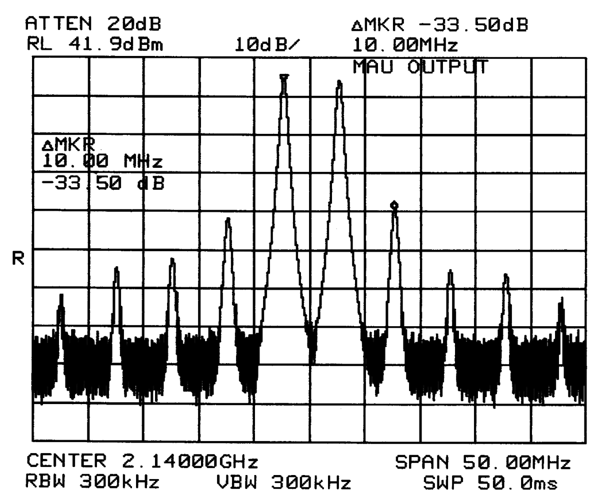

Fig. 3. 2-tones intermodulation characteristic of the main amplifier before linearization

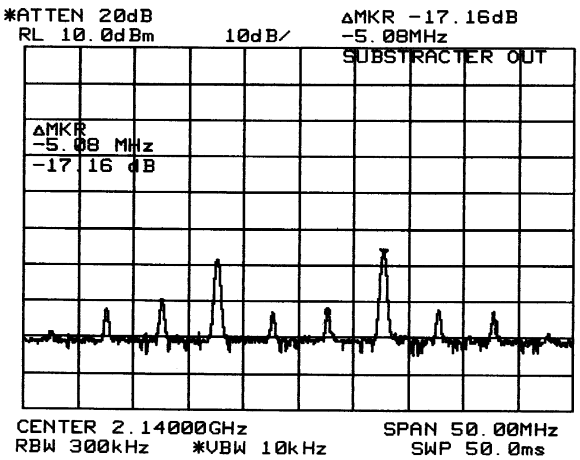

Fig. 4. Substracter output spectrum

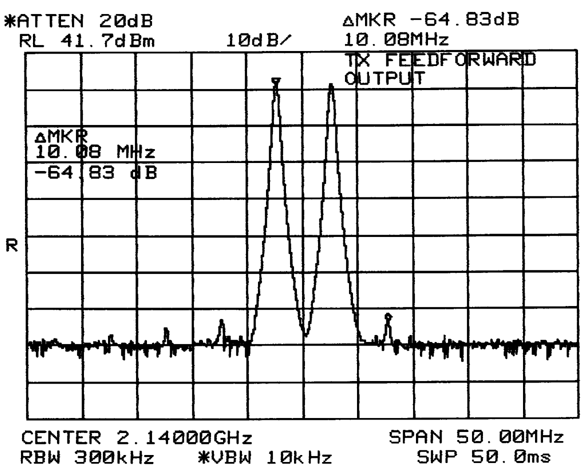

Fig. 5. 2-tones intermodulation characteristic of the feedforward amplifier after linearization

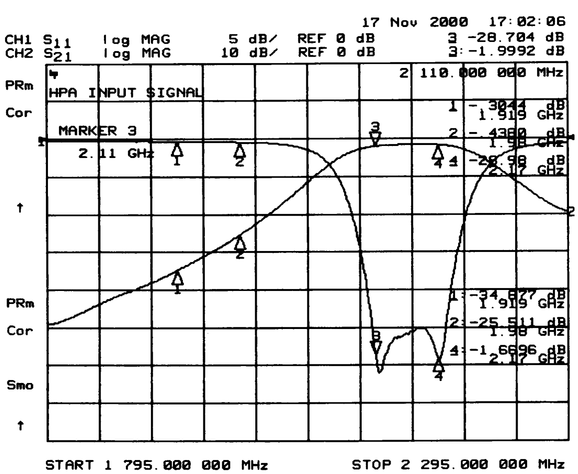

Fig. 6. Input signals before RX noises rejection

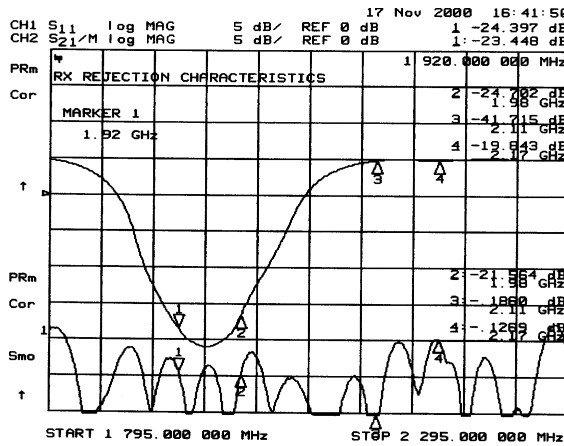

Fig. 7. RX band rejection characteristic

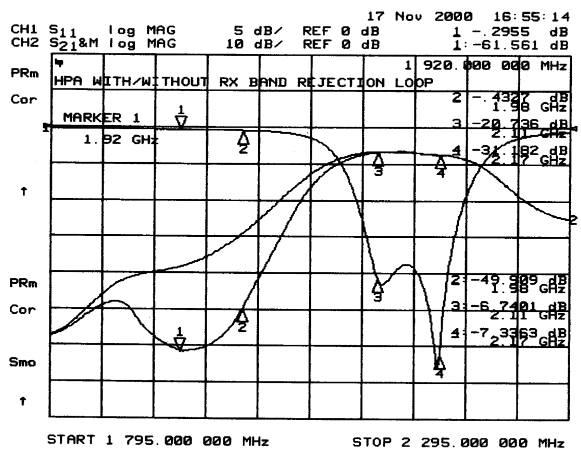

Fig. 8. Output characteristic of HPA with and without RX noises cancellation loop