DESIGN OF A RF FIXED PHASE CONTROL CIRCUIT USING ADAPTIVE VECTOR CONTROL

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In conventional feedforward type, the phase variation of delay line by external temperature has not considered. So, this phase variation makes main cause of the linearizer efficiency low. In this paper, the new type of vector phase controller using a vector theory is proposed to fix the phase variation of the delay line . As a result, when the input signal consists of one or two with the phase variation of ±10° in 10dB dynamic range, the phase of delay line is changed within 0.35°, and amplitude is changed under 0.07dB.

1 Introduction

Linear power amplifier(LPA), which is one of the essential component of the various digital communication, is usually consist of high power amplifier and linearizer [1][2]. The most linearizers employ one of three schemes, i.e. feedforward type, predistortion type and feedback type, of which the first type is known as best. In conventional feedforward type (Fig.1), the phase variation of delay line by external temperature has not been considered. If feedforward linearizer is controlled with analog controller, unnecessary phase variation of delay line on operating temperature must be considered. In this paper, a new phase controller is designed to fix the phase of delay line for analog controlled linear power amplifier.

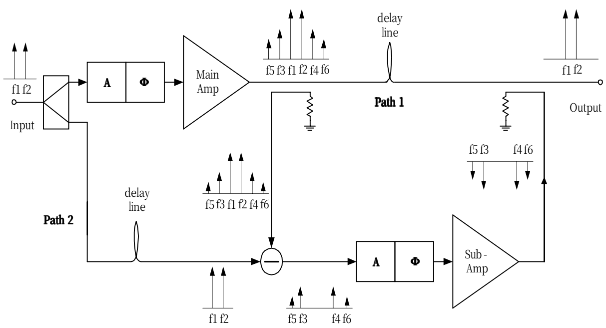

Fig.1. The linear power Amplifier using feedforward-type linearizing method

2 The operation of vector phase

Carrier group delay line using coaxial cable causes phase variation in a wide temperature range. This phase variation is caused by thermal expansion coefficient variation. Thermal expansion coefficient variation is caused by the change of temperature of a conductor and dielectric composing coaxial cable. In this paper, it is disregarded that insertion loss variation of group delay line caused by external temperature variation. Because insertion loss variation caused by temperature variation is very small and insertion loss can be fixed with the proposed method in this paper. Vector phase control theory is presented in Fig.2

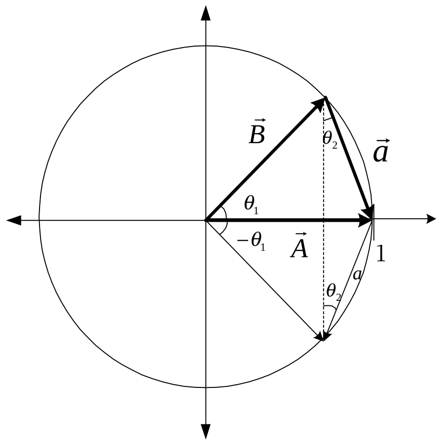

Fig. 2. Operation of Vector phase control circuit

Let $\vec{A}$ is output signal of delay line at the normal temperature and $\vec{B}$ is output signal of delay line on condition of temperature change and $\vec{a}$ is arbitrary additional signal. When phase of signal is changed as much as $-\theta_1 \sim \theta_1$ at the temperature which delay line is operated, if arbitrary additional signal component $\vec{a}$ is added to output signal $\vec{B}$ of delay line, then final output signal of delay line can be reconstructed output signal $\vec{A}$ at the normal temperature as,

$$\vec{A} = \vec{B} + \vec{a} \tag{1}$$

This equation (1) means that constant output signal can be always made when signal $\vec{a}$ satisfying the equation (1) is added to $\vec{B}$. If signal $\vec{B}$ is normalized by amplitude of signal $\vec{A}$ at the normal temperature, the information of additional signal $\vec{a}$ can be written as,

$$\cos\theta_1 + a \cdot \sin\theta_2 = 1 \tag{2}$$

$$\sin\theta_1 = a \cdot \cos\theta_2 \tag{3}$$

$$a = \frac{\sin\theta_1}{\cos\theta_2} \tag{4}$$

Equation (4) is substituted for equation(2). The θ_2 is found as,

$$\theta_2 = \tan^{-1}\left(\frac{1-\cos\theta_1}{\sin\theta_1}\right) = \tan^{-1}\left(\frac{2\sin^2\frac{\theta_1}{2}}{2\sin\frac{\theta_1}{2}\cos\frac{\theta_1}{2}}\right) = \tan^{-1}\left(\tan\frac{\theta_1}{2}\right) = \frac{\theta_1}{2} \tag{5}$$

Now, the amplitude of additional signal is found as,

$$|a| = 20\log\left|\frac{\sin\theta_1}{\cos\frac{\theta_1}{2}}\right| \ [dB] \tag{6}$$

Consequently, if phase of delay line is changed $-\theta_1 \sim \theta_1$, maximum amplitude of arbitrary additional signal is calculated by equation (5) and phase range of that is $-\theta_1/2 \sim \theta_1/2$. When phase variation of delay line is occurred in a range of $\theta_1 = \pm 10°$, the additional signal has phase variation of $\theta_2 = \pm 5°$ and carrier wave to amplitude of signal ratio as below.

$$|a|_{\max} = 0.087(or\ -15.17dB) \tag{6}$$

This additional signal is added to output signal $\vec{B}$ by vector synthesis method, the information of original signal is maintained. At this time, the smaller the phase variation of delay line is, the smaller the amplitude and phase of additional signal is. Fig.3 shows the overall block diagram of a RF fixed phase control circuit using adaptive vector control scheme and test circuit board. In this paper, proposed circuit is divided into divider [Module A], main path [Module B], test board circuit [Module C] for measurement delay line DL1, AGC[Module D] controlling magnitude constantly, ALC[Module E,F], APC[Module G] controlling phase constantly. Delay line DL2 is also delay line to test phase of DL1. Phase shifter(ϕ_1) is used to change phase of delay line DL1, which is equivalent to change phase of delay line by external temperature.

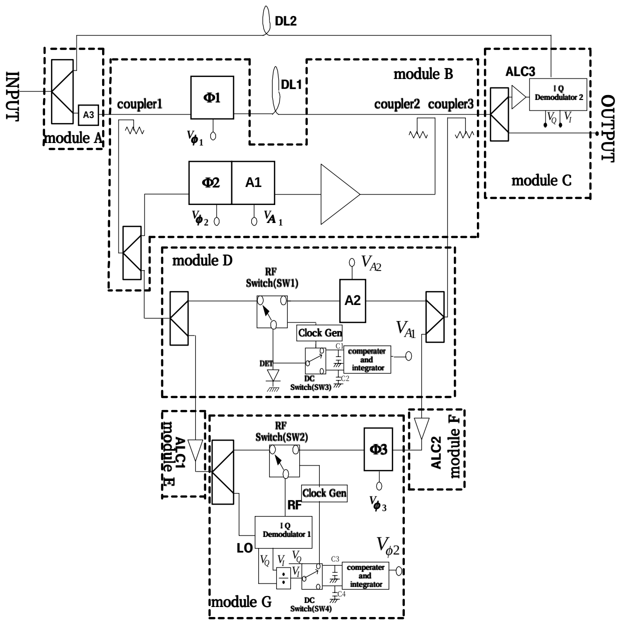

Fig.3. Block diagram of a RF Fixed Phase Control Circuit

In Fig.3, module A, module C, delay line DL2 and variable phase shifter (ϕ_1) of module B are modules for test, these modules are not included in real circuit. When the input signals having constant level put into module A, these signals are passing by low phase shift variable attenuator and then output level of changed with constant phase. Delay line DL1 represents delay line located on the main path of feedforward type circuit. Variable phase shifter (ϕ_1) in front of delay line DL1 substitutes for phase variation caused by temperature variation in delay line DL1. Output signals of module A put into coupler 1. In coupler 1, the most of input signals are transmitted to delay line DL1 and give rise to group delay. Partially extracted signals by coupler 1 put into variable phase shifter (ϕ_2). These signals are passing by variable attenuator A1 and amplifier and then are combined with main signal having group delay in combiner (coupler 2). So that, output signals of delay line have a constant amplitude and phase. In coupler 3, a part of output signals is extracted and then these signals represent the information about amplitude and phase of final output signal.

As a part for an automatic control, ALC1 and ALC2 are used to maintain constant input level of RF and LO signals that fed into mixer of I & Q demodulator. Also, automatic gain controller (Module D) and automatic phase controller (Module G) are used separately to control the gain and phase constantly.

3 Experiment and results

The reflective phase shifter is adapted as a variable phase shifter for a good reflection coefficient (return loss). The low phase shifting attenuator is adapted as a variable attenuator. For the amplitude of signal is controlled, the phase is not changed [3][4]. The pin diode is UPP-9401 of Microsemi and the varactor diode is 1T362 of Sony. The 3dB Divider is S03A888N1 of RF Power. The mixer used to implement I & Q demodulator is TUF-2SM of Minicircuits. Table 1 shows measurement result in case of 1-tone signal and 2-tone signals. When input signal consists of 1-tone signal(880MHz) in 10dB dynamic range (0dBm~10dBm) on condition that phase variation of delay line is about ±10°, the measurement result is obtained phase variation within 0.36° and insertion loss variation under 0.06dB. Also, when input signal consists of 2-tone signals (877MHz, 882MHz), the measurement result is obtained phase variation within 0.35° and insertion loss variation under 0.07dB.

TABLE 1 Measured results of phase/amplitude using 1-tone signal and 2-tone signals

P_{in}	Variable Phase Shifter1	**1-TONE (880MHz)**				**2-TONE (877MHz, 882MHz)**				
		Control Voltage		Output Phase	P_{out} (dBm)	Control Voltage		Output Phase	P_{out} (dBm)	
		ATT (V)	Phase2 (V)	Phase (deg)	880 MHz	ATT (V)	Phase2 (V)	Phase (deg)	877 MHz	882 MHz
10dBm	9V(+10°)	3.85	9.98	28.48	-1.17	3.98	9.48	12.15	-1.20	-1.20
	7V(-10°)	1.18	10.72	28.48	-1.23	1.57	10.43	12.50	-1.23	-1.23
5dBm	9V(+10°)	3.56	9.77	28.73	-6.17	3.80	9.36	12.15	-6.20	-6.20
	7V(-10°)	1.04	10.63	28.48	-6.20	1.43	10.40	12.50	-6.20	-6.20
0dBm	9V(+10°)	3.25	9.55	28.37	-11.20	3.60	9.23	12.50	-11.23	-11.23
	7V(-10°)	0.90	10.49	28.48	-11.20	1.27	10.36	12.50	-11.20	-11.20
Error				0.36	0.06 dB			0.35	0.07 dB	

4 Conclusion

In this paper, the new type of vector phase controller using a vector theory is proposed to fix the phase variation of the delay line. In phase variation of ±10° in 10dB dynamic range, phase of delay line is changed within 0.35° and amplitude is changed under 0.07dB. In conventional type, the phase variation of delay line by external temperature has not considered. So, this phase variation makes to cause the linearizer efficiency low. If the RF fixed phase controller proposed in this paper is used to analog controlled feedforward linearizer, a fixed phase characteristics will be obtained at external temperature variation.

Acknowledgments

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