A Technical Study on Microwave FM Locked in Phase of Telemetry Transmitters

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ABSTRACT

This paper describes techniques on the microwave FM locked in phase of transmitters in the reentry telemetry system. A few scheme configurations on the microwave FM locked in phase, its circuit characteristics and applications are analyzed. Research results show that the two-point injection microwave FM locked in phase is suitable for the telemetry system, which code rate is higher, band of wide, and modulation response very well.

Key word: Reentry Telemetry, Transmitter, FM Locked in Phase, High Code Rate

1 Introduction

The frequency modulation (FM) transmitter used in the reentry telemetry system is part of the airborne equipment. Generally, its volume is small, operation stable and reliable. And its characteristics are required to meet system targets. In the past, the circuit scheme of this transmitter was that the frequency was first modulated in the crystal oscillator, then the modulated signal was repeatedly doubled on the frequency, filtered and amplified. There are many defects in this scheme, that is, the circuit composition is complex, the adjustment difficult, and the performance stabilization no good. Therefore, a FM scheme, which circuit composition is simple, the adjustment easy, and performances meet the reentry telemetry system's demand, is sought for us. With the development of the phase-lock, the frequency modulation and MMIC techniques, a FM transmitter can be composed by a microwave phase-lock FM oscillator and a MMIC power amplifier. A critical technique of this transmitter is the microwave FM locked in phase, including one-point, quasi-two-point and two-point injection microwave FM locked in phase. They respectively suit for reentry telemetry systems which requirement is different for the modulating signal and modulated performances.

2 One-point injection microwave FM locked in phase

The modulating signal is directly put on the input terminal of the microwave voltage controlled oscillator (VCO) that the output frequency of VCO is linear with the modulating signal. This FM scheme is called the one-point injection microwave FM locked in phase. Its circuit schematic is shown Fig.1. Fig.2 is its phase model. In figures, CO is the crystal oscillator, PMC the pre-modulating circuit, PD the phase detector, LF the loop filter, K_v the voltage controlled sensitivity, K_d the discriminating sensitivity of PD, N the total dividing frequency number of times, F(S) the transmission function of LF, and $U_\Omega(S)$ the modulating signal.

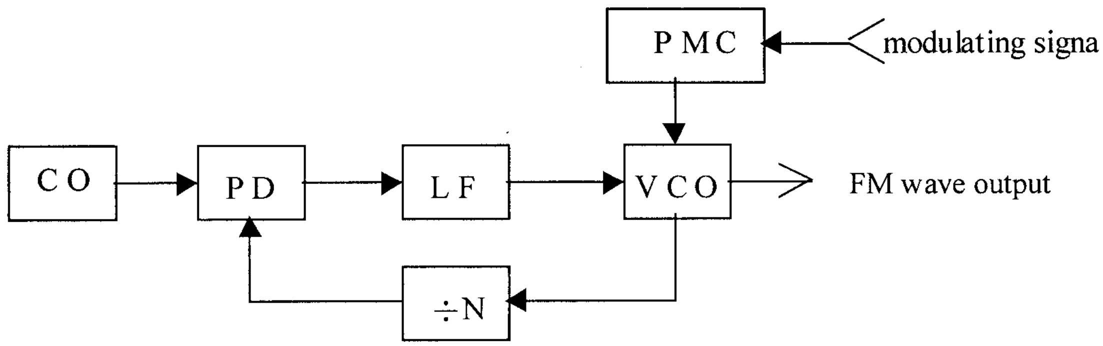

Fig. 1 the circuit schematic of one-point injection microwave FM locked in phase

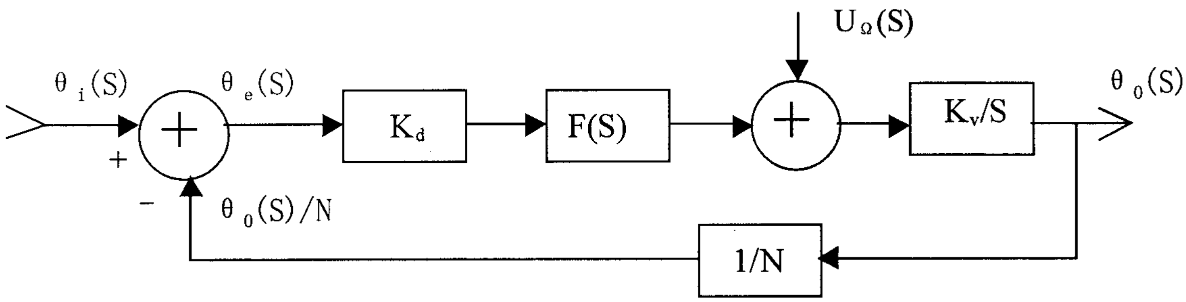

Fig. 2 the phase model of one-point injection microwave FM circuit locked in phase

Under the phase-lock FM circumstances, $U_\Omega(S)$ and the controlling signal are added so that the frequency of VCO is controlled. From the phase model of Fig.2, we have

$$\begin{cases}\theta_i(S) - \theta_o(S)/N = \theta_e(S) \\ [\theta_e(S)K_d F(S) + U_\Omega(S)]K_v/S = \theta_o(S)\end{cases} \quad)1\_$$

In order to simplify, supposing θ_i, = 0, the equation (1) is solved to obtain

$$\theta_0(S) = \frac{K_v}{S} H_e(S) U_\Omega(S)$$

In above the formula, $H_e(S) = 1/[1+K_v K_d F(S)/NS]$

So the produced modulation frequency deviation is

$$\Delta\omega(S) = S\theta_o(S) = K_v H_e(S) U_\Omega(S) \quad (2)$$

$H_e(S)$ in the formula (2) is the transmission fuction of the modulation frequency deviation and the modulating signal, as well the error transmission function of the second-order phase locked loop. In view of this, there is the high pass characteristic in the loop for the modulating signal. The lowest frequency of the modulating signal must be higher than the loop cut off frequency so that the phase locking FM is directly made in a VCO. The defect of this FM scheme is that modulation performances are relative with the loop band -width.

In order to meet the demand of modulating performances, the designed loop band-width is generally lower so that the loop locked one is reduced, and the phase lock of a FM source is very difficult.

We have made the experimental research on the circuit of one-point injection microwave FM locked in phase. The result is shows that this scheme is only suitable for the telemetry system which code rate is lower than 400 kb/s. We have adopted it to develop out 200 kb/s FM telemetry transmitter. This transmitter has been used in practice.

3 Quasi-two-point injection microwave FM locked in phase

The modulating signal is divided into two parts. One is fed to the input terminal of VCO that its output frequency is linear with this signal. So direct FM is realized. Another is put on the input terminal of the loop filter by a integrator. Then VCO' s phase is modulated that FM is indirectly realized. This FM scheme is called as the quasi-two-point injection microwave FM locked in phase. Its circuit schematic. is shown Fig. 3. Fig. 4 is its phase model. In the figure, K_m is the integral time constant of the integrator.

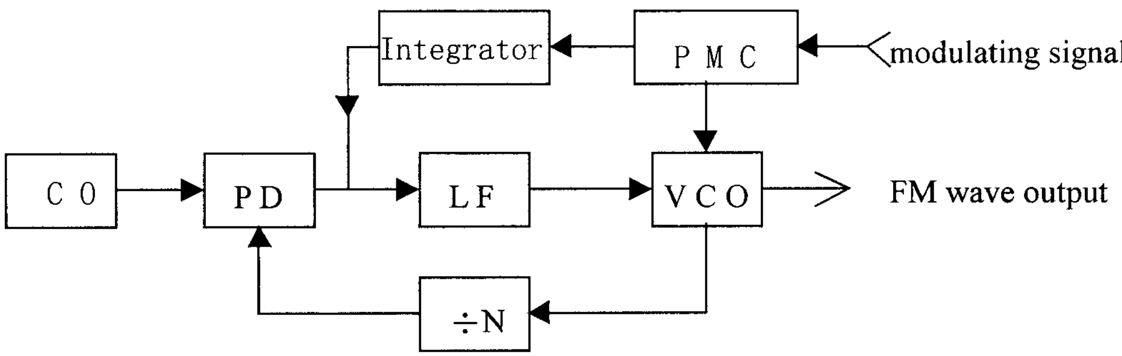

Fig. 3 the circuit schematic of quasi-two-point injection microwave FM locked in phase

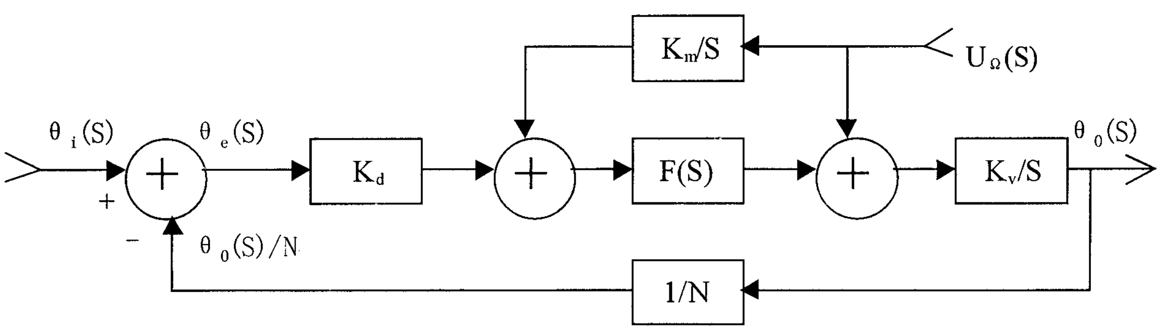

Fig. 4 the phase model of quasi-two-point injection microwave FM circuit locked in phase

From this phase model, we obtain

$$\begin{cases} \theta_i(S) - \theta_o(S)/N = \theta_e(S) \\ [\theta_e(S)K_d F(S) + K_m F(S) U_\Omega(S)/S + U_\Omega(S)]K_v/S = \theta_o(S) \end{cases} \quad (3)$$

In order to simplify the modulating performance analysis, supposing $\theta_i(S) = 0$, the equation (3) is solved to obtain the total loop output phase change with $U_\Omega(S)$

$$\theta_o(S) = \frac{K_v}{S}\left[\frac{K_m F(S)/S + 1}{1 + K_v K_d F(S)/NS}\right] \times U_\Omega(S)$$

So, the resulting modulated frequency deviation is

$$\Delta\omega(S) = S\theta_o(S) = K_v\left[\frac{K_m F(S)/S + 1}{1 + K_v K_d F(S)/NS}\right] \times U_\Omega(S)$$

Making $K_m N / K_d - K_v = 0$, above formula is turned into

$$\Delta\omega(S) = K_v U_\Omega(S) \tag{4}$$

According to the formula (4), so long as the integrator is reasonably designed, and the integral constant K_m is selected to meet the condition

$$K_m = K_v K_d / N \tag{5}$$

The modulating characteristic of the quasi-two-point injection FM becomes a smooth straight line K_v, that is, the wide-band modulated performance, which has nothing to do with the loop response, is obtained. This technique characteristic just meets FM requirements of high code rate signals. The quasi-two-point injection FM scheme is generally suitable to the telemetry system which code rate is not high than 5 Mb/s. This scheme has been used to develop out 2 Mb/s FM telemetry transmitters, which will be put into the practice usage.

4 Two-point injection microwave FM locked in phase

The modulating signal is similarly divided into two parts. One is fed to VCO that its output frequency is linear with this signal. After another is put on the integrator, it modulates the output signal phase of the crystal oscillator. The phase-modulated signal is taken for the reference source to lock in the loop' s phase. This FM scheme is called as the two-point injection microwave FM locked in phase. Its circuit schematic is shown Fig. 5. Fig. 6 is its phase model. In the figure, K_p is the modulating index of the phase modulator.

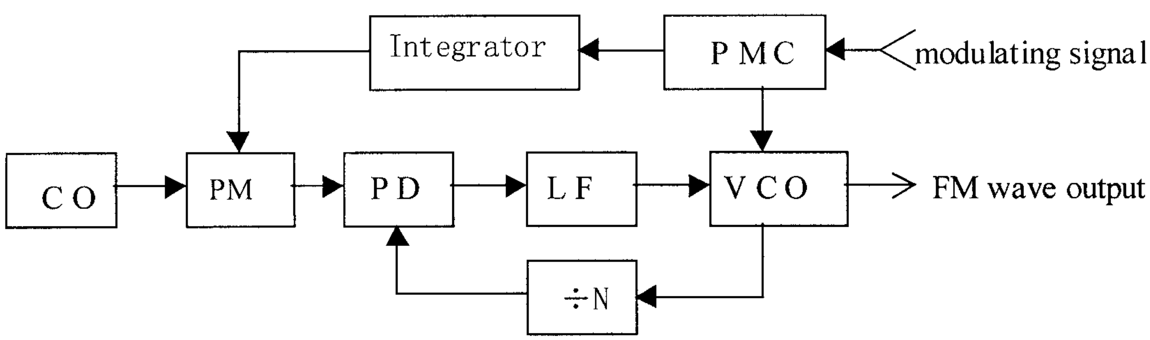

Fig. 5 the circuit schematic of two-point injection microwave FM locked in phase

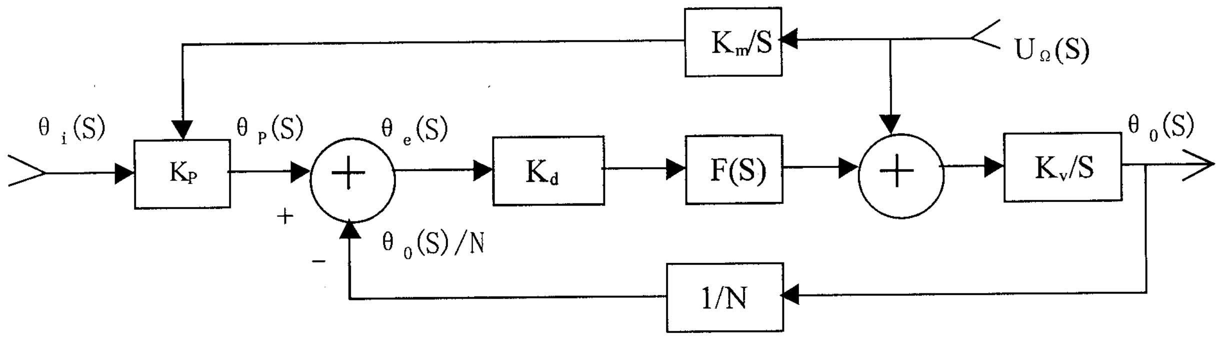

Fig. 6 the phase model of two-point injection microwave FM circuit locked in phase

From the phase model, we get

$$\begin{cases}\theta_P(S)-\theta_o(S)/N=\theta_e(S)\\ [\theta_i(S)+K_mU_\Omega(S)/S]K_P=\theta_P(S)\\ [\theta_e(S)K_dF(S)+U_\Omega(S)]K_v/S=\theta_o(S)\end{cases} \tag{6}$$

Supposing $\theta_i(S) = 0$, the equation (6) is solved to gain the total loop output phase change

$$\theta_o(S)=\frac{K_v}{S}\left[\frac{K_mK_dF(S)/K_PS+1}{1+K_vK_dF(S)/NS}\right]\times U_\Omega(S)$$

When the following condition is satisfied

$$K_m=K_vK_P/N \tag{7}$$

We have

$$\theta_o(S)=\frac{K_v}{S}\times U_\Omega(S)$$

So the resulting modulated frequency deviation is

$$\Delta\omega(S)=K_vU_\Omega(S) \tag{8}$$

On the basis of the above-mentioned analysis, provided the integrator meets the demand of the formula (7), the modulating characteristic of the two-point injection FM has nothing to do with the loop response. This technique characteristic is similarly suitable for the high code rate signals FM. In the experimental circuit research, 10 Mb/s FM has been realized. It will have larger application prospects.

5 Conclusion

The technique on the microwave FM locked in phase is key one of the new-type reentry telemetry system development. In the transmitter which code rate is low and modulated characteristic requirement not high, one-point injection microwave FM locked in phase can be selected. This transmitter circuit is comparatively simpler, and its adjustment easy. Quasi-two-point and two-point injection microwave FM locked in phase have the wide-band modulated performance, which has nothing to do with the loop response. This performance meets the FM requirement of high code rate telemetry-signal. They will be extensively used in the development of the new one-generation telemetry transmitter, which code rate is higher.

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