A Novel Phase Noise Reduction in Oscillator Using PBG(Photonic Band Gap) Structure and Feedforward Circuit

Chulhun Seo

Abstract

In this paper, PBG structure and feedforward circuit has been used to suppress the phase noise of the oscillator. Microstrip line resonator have low Q, but we can obtain high LO power by feedforward circuit and improve the resonator Q by the PBG, simultaneously. The proposed oscillator which uses PBG and feedforward circuit shows 0~20 dB phase noise reduction compared to the conventional oscillator. We have obtained −115.8 dBc of phase noise at 100 kHz offset from 2.4 GHz center.

Key words : Phase Noise, PBG, Feedforward, Oscillator, Circuit.

Ⅰ. Introduction

Phase noise is most important factor in the performance of oscillator. Many methods have been proposed to reduce the phase noise of oscillator. One way is increment of resonator Q of oscillator and the other way is to use proper transistor having less flicker noise. YIG and DR resonator have been used to increase resonator Q of oscillator. Recently, the feedforward circuit has been employed in reducing the phase noise of oscillator[1]~[7]. Photonic band gap(PBG) structures are periodic structure in certain bands of frequencies are not passed. The WDM system needs very sharp filters to divide the wavelengths of optical signals and used PBG filter. Now PBG structures have been used to improve radiation pattern antenna and increase power efficiency of high power amplifiers in the microwave and millimeter region. A new PBG is used to reduce flicker noise, too. PBG structure can be realized in the MMIC, while it is hard to apply the external high Q resonator chip[8],[9].

In this paper, PBG structure has been added to the feedforward circuit to reduce the phase noise of oscillator.

Ⅱ. PBG Structure

PBG(Photonic Band Gap) structure is come from Bragg grating. It is periodic structure which reflect some frequency, so we can use this structure making stop-band. Similarly, a PBG structure is a periodic structure where electro-magnetic waves of some frequency bands cannot be propagated. PBG structures have been studied in the optical region and applied in microwave and millimeter wave circuits. Many research have been presented using PBG(Wide band-stop PBG, UC-PBG, and so on).

Fig. 1 is basic PBG for microstrip application. To make rejection characteristic on some band following equation is used.

$$-\beta = \beta - \frac{2\pi}{\Lambda} \tag{1}$$

$$\lambda_g = 2\Lambda \tag{2}$$

The microstrip line resonator using PBG structure will have advantage:

1) Simple fabrication because resonator is planar structure.

2) Phase noise reduction because high Q[9].

Ⅲ. Feedforward Circuit

A simplified feedforward circuits is shown in Fig. 2 G is the amplifier gain, K_1 is the coupler ratio. The main path without error correction goes from A to B. The error signal is derived from the left hand loop AC-AD. The error correction is then obtained from the upper path and the right hand loop AB-EB[1]~[7].

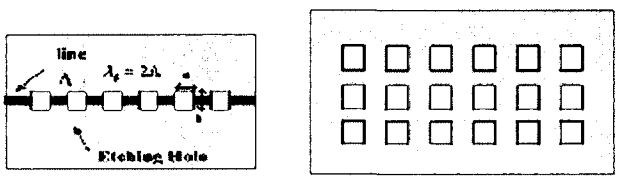

Fig. 1. Microstrip line with PBG on the ground.

Manuscript received November 30, 2005 ; revised December 7, 2005. (ID No. 20051130-046J)
School of Electronic Engineering, Soongsil University, Seoul, Korea.

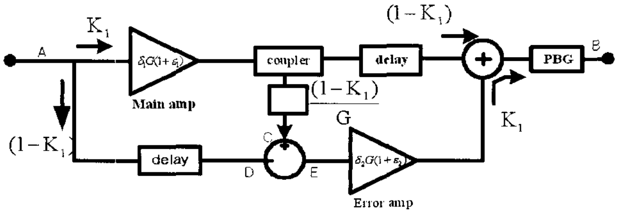

Fig. 2. Ideal feedforward circuit using PBG.

A phasor analysis is performance in [3], however a simplified analysis is performance here. The flicker noise of the main amplifier is represented as $(1+\varepsilon_1)$ and the error correcting amplifier as $(1+\varepsilon_2)$. The main amplifier balance is represented as δ_1 and δ_2. Note that perfect balance occurs is when $\delta=1$ therefore the suppression of each loop in decibels=10 log(1 − δ). The power transfer function of the amplifier shown in Fig. 3 is therefore:

$$P_T = K_1G(1-K_1)[\sigma_1\varepsilon_1(1-\sigma_2)\sigma_2\varepsilon_2(1-\sigma_1) - \sigma_1\varepsilon_1\sigma_2\varepsilon_2 + (\sigma_1 - \sigma_1\sigma_2 + \sigma_2)] \quad (3)$$

Where $K_1G(1-K_1)$ is the ideal amplifier gain. Assuming that δ_1 and δ_2 are close to one (of order 0.1 % to 1 %) and ε is very small then this equation simplifies to:

$$P_t + K_1G(1-K_1)[1+\varepsilon_1(1-\sigma_2)+\varepsilon_2(1-\sigma_1)] \quad (4)$$

If each loop suppression is assumed to be 23 dB and the flicker noise levels of each amplifier the same then a flicker noise suppression of 20 dB can be obtained. Of course the total noise cannot be suppressed below the noise figure of the feedforward amplifier.

Flicker noise is modulation noise which means that the ratio of sideband noise to carrier level is constant. This includes a method for deconvolving the internal noise sources within the device.

This paper proposed feedforward circuit using PBG structure. This is increment to feedforward's performance.

Ⅳ. Citing Previous Work

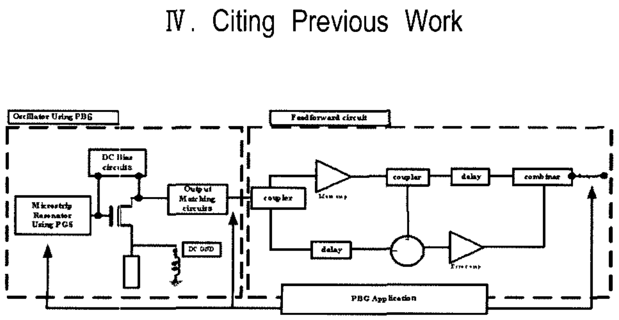

Fig. 3. Oscillator using PBG and feedforward circuit diagram.

Fig. 3 is proposed structure in this paper. It is the oscillator using feedforward and PBG. This structure is possible to apply in resonator, oscillator output, finally feedforward output.

Oscillator has been designed to single-ended topology. Because this type generally is used in millimeter wave band. CF00402 GaAs FET in Celeritek corporation has been used and DC bias is V_{ds}=5.5 V, I_{dss}=48.48 mA. Feedforward amp have been used ZHL-4240 in Mini-circuits company.

Fig. 4 show the PBG section etched on the ground plane under the 50 microstrip line. It is fabricated using a Teflon substrate of 0.76 mm thickness and a dielectric constant of 3.2. The length of the rectangle, a, is 7.96 mm and the period, b, is 15.92 mm. By adjusting the period of these cells, the harmonics of resonator frequency are suppressed and the resonator frequency nears the cutoff frequency 3 GHz.

The measured value is superior to simulation value. The fabricated PBG is so large, but size is quite small if a dielectric constant is high.

Fig. 5 shows measured phase noise of conventional and PBG employed oscillator. Conventional oscillator has phase noise of −82.84 dBc/Hz at 12 kHz offset, −94.88 dBc/Hz at 50 kHz offset, −100.9 dBc/Hz at 100 kHz, and the oscillator employing PBG in resonator has phase noise of −90.5 dBc/Hz at 12 kHz, −101.9 dBc/Hz, at 50 kHz offset, −110.5 dBc/Hz at 100 kHz. In output PBG insert PBG oscillator, phase noise of performance is −110.1 dBc/Hz at 12 kHz, −111.6 dBc/Hz at 50 kHz, −111.9 dBc/Hz at 100 kHz. In this case, phase Noise very excellent but output power is extremely low. In case of PBG cell is optimized, high performance is acquired. resonator insert PBG oscillator is superior than no PBG oscillator about 10 dBc/Hz.

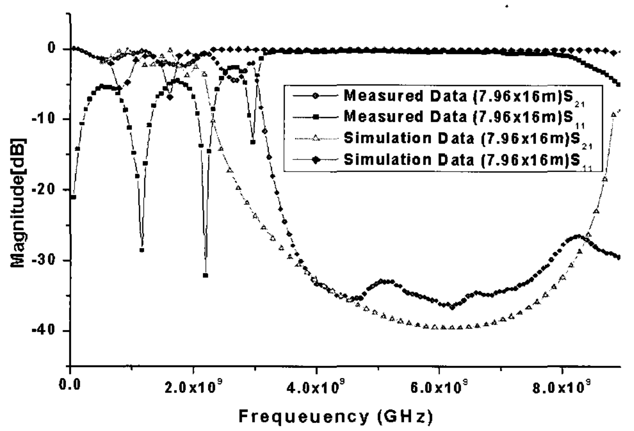

Fig. 4. Simulation and measured characteristics of the microstrip with PBG.

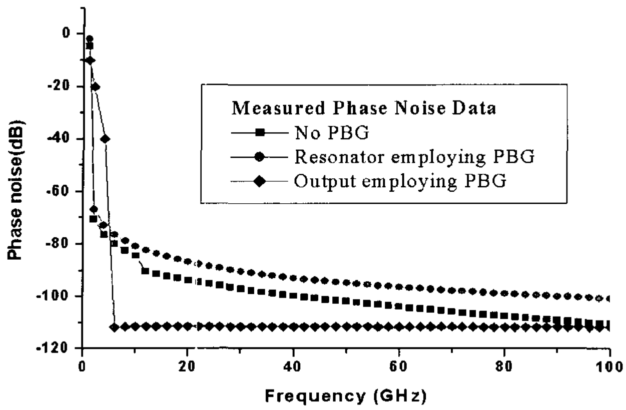

Fig. 5. Measured phase noise in oscillator.

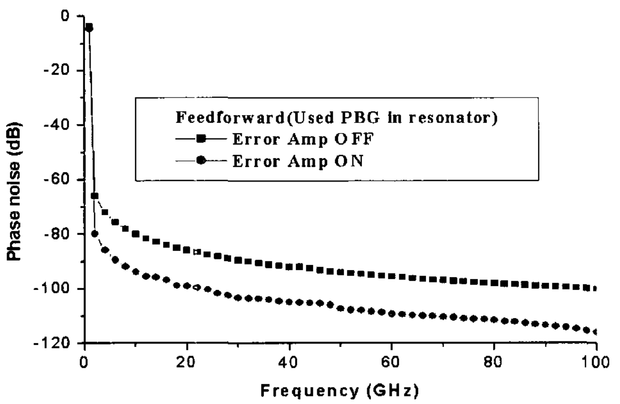

Fig. 6. Measured phase noise in oscillator(using PBG and feedforward).

Fig. 6 oscillator using PBG insert in resonator-add feedforward circuit which is applied PBG. When error amplifier turn on, output power is 27 dBm, turn off 24 dBm. When error amplifier turn off, phase noise −81.4 dBc/Hz at 12 kHz offset, −93.88 dBc/Hz, at 50 kHz offset, −99.9 dBc/Hz at 100 kHz offset. When error amplifier turn on, −95.33 dBc/Hz at 12 kHz offset, −107.26 dBc/Hz at 50 kHz offset, −115.8 dBc/Hz at 100 kHz offset.

V. Conclusion

For phase noise reduction, we proposed oscillator employing PBG and feedforward circuit. The proposed oscillator has less 15 dBc/Hz of phase noise than conventional oscillator. This is added to feedforward circuit and the high output power has been obtained(27 dBm). It will possible to reduce phase noise when PBG cell and feedforward circuit are optimized respectively.

This work was supported by Soongsil University Research Fund.

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Chulhun Seo

He received his B.S., M.S. and Ph.D. degrees from Seoul National University, Korea, all in Electronics Engineering in 1983, 1985, 1993, respectively. From 1993 to 1995, he was a Postdoctoral Research Scientist at the Massachusetts Institute of Technology, Cambridge. He has been a Professor at Soongsil University since 1993. His research interests include wireless and microwave components, microwave integrated circuits and optical sensors as well as microwave circuits and RFICs.