



DSM Fractional-N PLLs Spur Optimization

1. Introduction

Peregrine's Delta-Sigma modulated (DSM) Fractional-N PLLs include PE9763, PE83363 and some of new products yet to be released. They all have excellent phase noise and low spur due to the incorporation of DSM scheme, which are important for all applications, especially in a small frequency step size application.

A traditional fractional-N PLL achieves a desired fractional ratio by dithering the frequency between two values with corresponded N value between n and n+1 integers in a limit numbers of weighting ratio, like 1:31, 2:30, 3:29, 4:38, ... 30:2 or 31:1, where $N = (\text{RF frequency})/(\text{comparison frequency})$ and the comparison frequency is the phase detector frequency. The resulting fractional ratio is 1/32, 2/32, 3/32, 4/32, ... 30/32, or 31/32, respectively. The spurious signal, commonly called spur, is usually large because of the fixed ratio in dithering between two frequencies.

On the contrary, a DSM fractional-N PLLs allows dithering of 4 frequencies at MASH 1-1 mode or 8 frequencies at MASH 1-1-1 mode depending on whether the MS2_SEL is at "HIGH" or "LOW", respectively, to achieve the desired frequency fraction. The MASH 1-1 mode is a second order fractional dithering which involves 4 ($=2^2$) N values (n-1, n, n+1, n+2). The MASH 1-1-1 mode is a third order fractional dithering which involves 8 (2^3) N values (n-3, n-2... n+3, n+4). The spurious signal in DSM Fractional-N PLLs is greatly reduced due to DSM scheme.

This report summarizes the general PE9763 spur behavior and how to take advantage of this behavior to achieve low spur in a small frequency step application.

2. Spur

The spurious signal (spur for short) of a DSM PLL occurs at a frequency offset from the integer-N frequency. The integer-N frequency is defined as the allowed frequency should the PLL run in the integer-N mode. For example, the PE9763 is running with a comparison frequency (F_c) of 20 MHz. The allowed frequency in the integer-N mode is the multiple of the F_c , like 1880, 1900, 1920, 1940 MHz, etc. subject to M and A counter register restriction. Thus, a spur will occur at 10 kHz offset from RF 1920.01 MHz carrier, 20 kHz offset from RF 1920.02 MHz, 200 kHz offset from RF 1920.2 MHz, etc. Table 1 lists few spur offsets as well as the spur magnitude with a loop bandwidth 60 kHz. Note that the harmonics of the spur which are smaller in magnitude than the primary were not listed.

Table 1. Spur of carrier frequency near Integer-N frequency 1920 MHz.

RF freq (MHz)	Integer-N freq (MHz)	Spur offset = RF - (Integer-N freq) (kHz)	Spur (dBc)
1920.01	1920	10	-40.0
1920.025	1920	25	-40.0
1920.05	1920	50	-39.0
1920.10	1920	100	-44.5
1920.20	1920	200	-54.5
1920.50	1920	500	-76.0

Figures 1 and 2 show the spectrum analyzer plots of various frequencies, from 1920.5 to 1920.05 MHz in Fig. 1 and from 1920.025 to 1920.01 MHz in Fig. 2. The X-axis (frequency) is plotted as the difference from the RF carrier frequency so that they can all be plotted in the same plot. The loop bandwidth was designed for 60 kHz at unity gain and approximately 75 kHz at 3 dB.

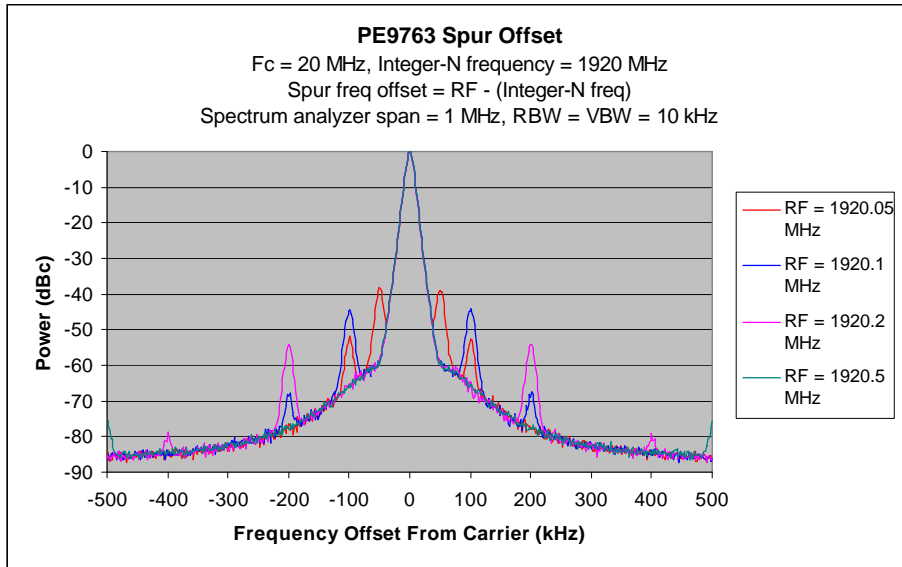


Figure 1. Spectrum analyzer plots of various RF frequencies from 1920.5 to 1920.05 MHz.

As shown in Figs. 1 and 2, the closer the RF frequency is to an integer-N frequency, the worse is the spur magnitude. All spurs including the spur harmonics were negligible, less than -70 dBc, when the frequency offset is 500 kHz or more. The spur of an integer-N frequency (Frequency offset is 0 in Figs. 1 and 2) is at 20 MHz offset from the carrier and is very small, less than -80 dBc.

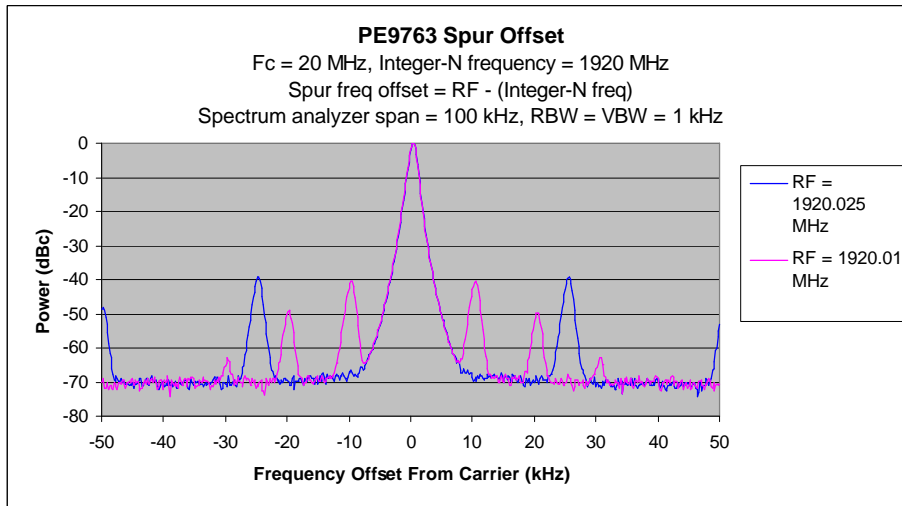


Figure 2. Spectrum analyzer plots of RF frequencies 1920.025 to 1920.01 MHz.

Figure 3 shows the spur plot of another PE9763-Ek board. The RF frequency was stepped through the integer-N frequency 1920 MHz at offset from -600 kHz to +600 kHz in various frequency step sizes. Regardless of the frequency step size, the spurs become less than -80 dBc and negligible once the RF frequency is 500 kHz or more from the integer-N frequency.

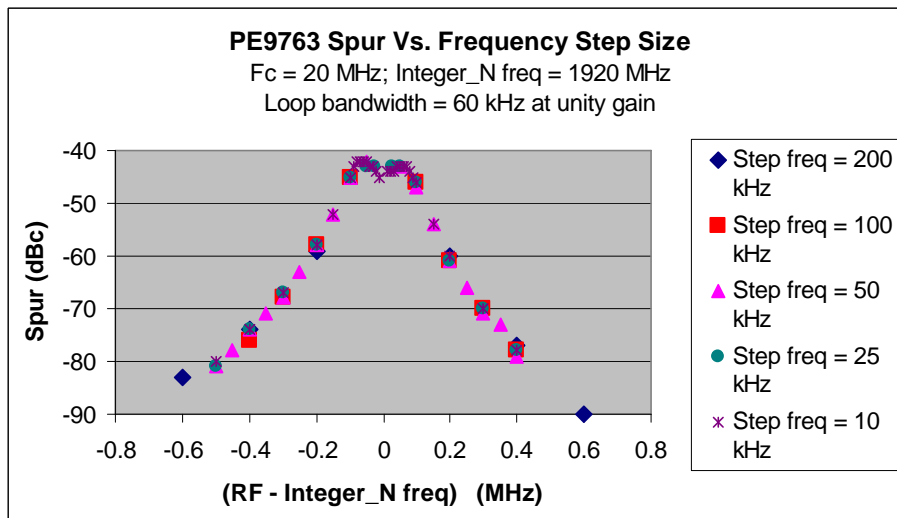


Figure 3. Spur of various RF frequencies stepped through the integer-N frequency 1920 MHz at offset from -600 kHz to +600 kHz in various frequency step sizes.

3. Optimizing Comparison Frequency for Minimum Spur

Previous section shows that the spur is negligible once the RF frequency is 500 kHz from an integer-N frequency and the integer-N frequencies have a separation of the comparison frequency value. By proper selecting a comparison frequency, the spur in the frequency we are interested could be small. Figure 4 shows the spur across RF frequency from 1900 to 1940 MHz with a comparison frequency of 20 MHz. Excluding 500 kHz from the integer-N frequency as the high spur area, the rest of frequency region, like from 1900.5 to 1919.5 MHz and from 1920.5 to 1939.5 MHz, have spur less than -80 dBc. These frequency ranges can cover a lot of step number in a small frequency step size application.

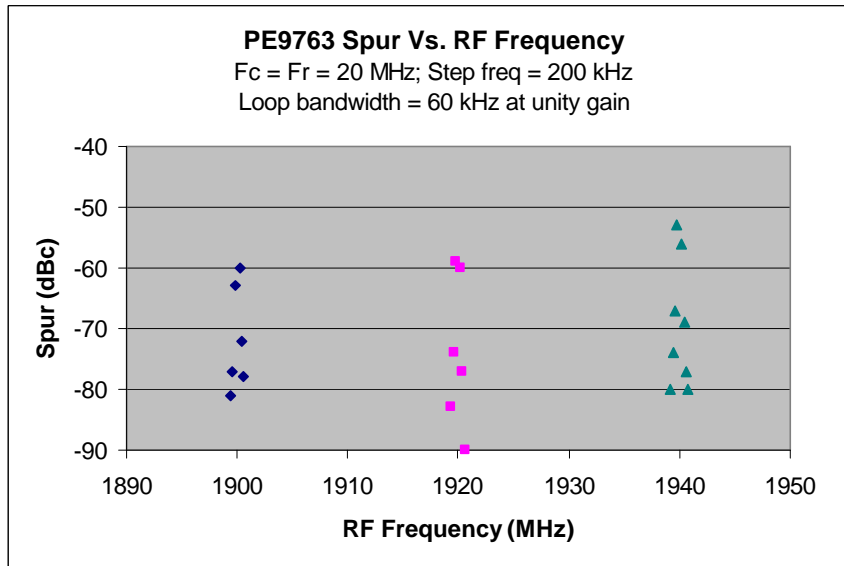


Figure 4. Spur across RF frequency from 1900 to 1940 MHz. Comparison frequency = 20 MHz.

If an application requires a frequency region around 1920 MHz, the spur will be bad around 1920 MHz if F_c is 20 MHz as shown in Fig. 4. However, the F_c can be changed to 14.286 MHz with a reference of 100 MHz. Figure 5 shows the spur across RF frequency from 1914 to 1929 MHz. The spur is negligible from 1914.7 to 1928 MHz.

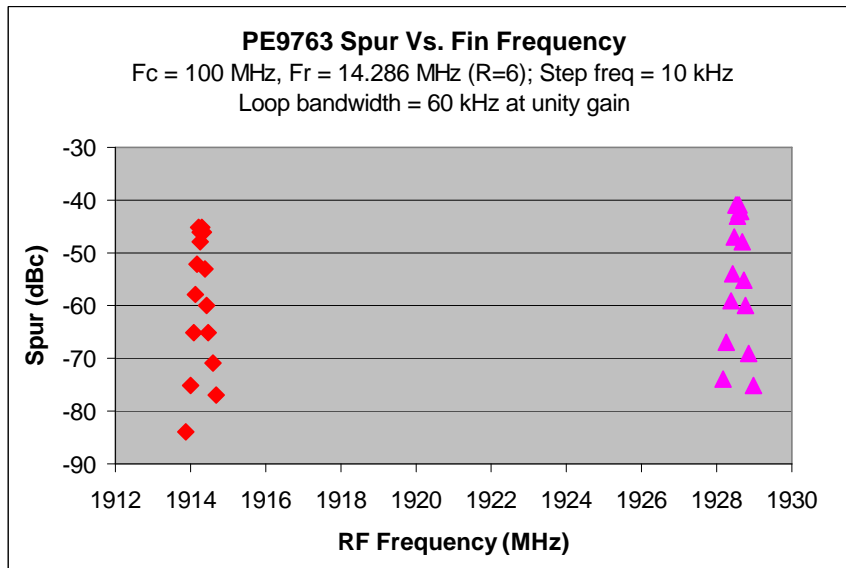


Figure 5. Spur across RF frequency from 1914 to 1929 MHz. Comparison frequency = 14.286 MHz.

4. Conclusion

It has been shown that spur in the frequency region can be negligible by properly selection the comparison frequency.

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