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Using DDS Aliasing to extend its frequency range

1.

Introduction

The Nyquist theorem limits the normal DDS range up to the half of the clock frequency. In practice, it is advised not to exceed a third. To obtain frequencies around 100MHz we need at least a 200MHz clocked DDS. Above the Nyquist limit, the output is no longer a unique sine wave. It shows an infinity of frequencies like the discontinuous wave spectrum. They are called aliases or images.

Fig 1 shows the spectrum envelope of a 100MHz clocked DDS for a 45MHz nominal output. The aliasing generates frequencies that could be interesting as they are beyond half of the clock fre-

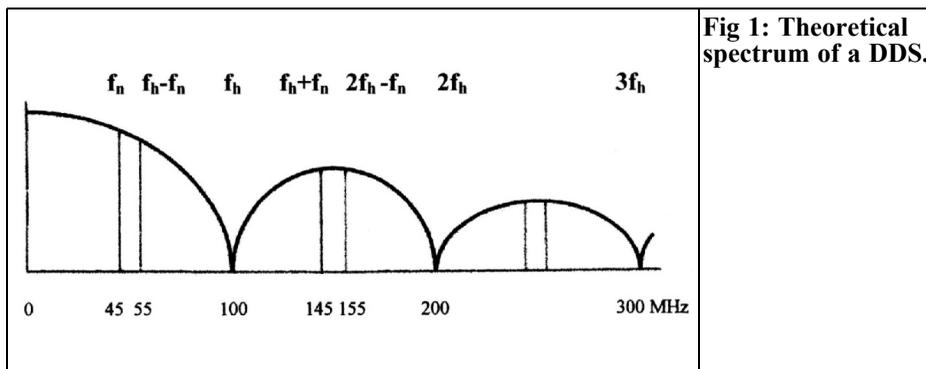
quency. Their levels decrease with the frequency but they remains usable. In the appendix, maths readers will find some references about the cardinal sinus function that governs the spectrum generation.

We can use a DDS far beyond half its clock frequency using aliases produced. Only careful filtering is needed to extract the desired frequency.

2.

An example

We need a 108.009MHz signal as a source for a 10368.900MHz beacon. Let us take a 100MHz DDS but with an 80MHz clock. Set up the nominal fre-



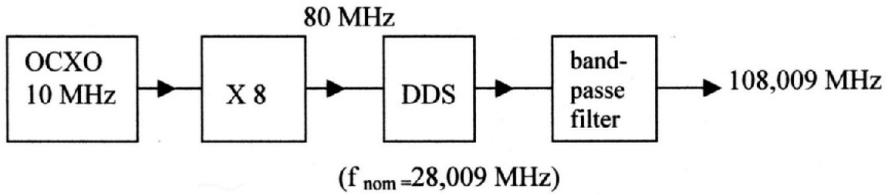


Fig 2: Block diagram of the VHF source.

quency at 28.009MHz.

We obtain an alias at :
 $f_c + f_n = 80 + 28.009 = 108.009\text{MHz}$.

Another alias is at :
 $2 f_c - f_n = (80 \times 2) - 28.009 = 131.991\text{MHz}$

Other frequencies are present as shown by Table 1 which gives some measurements (for a 28MHz nominal DDS frequency).

We have to filter the output in order to eliminate undesirable frequencies, mainly at 131.991MHz which is the closest to the desired frequency. A double pole bandpass filter like the NEOSID 22522/51138 or a crystal filter as described in [2] can do that. Fig 2 shows the block diagram of this VHF source.

To produce an 80MHz clock signal, we

can use the same method as for the synthesizer F5CAU/F9HX [2]. The precise and stable output of a 10MHz OCXO is squared by a 74HC4046 to get a CMOS signal that is harmonic rich. The desired harmonic is selected by a band-pass filter and then amplified to get the required level for a DDS clock. This method can also be used to produce a high stability 100MHz clock (Fig 3). We can also use a 100MHz clock and an 8MHz nominal frequency DDS to get a larger spacing between the two aliases:

$$f_c + f_n = 100 + 8 = 108\text{MHz}$$

and

$$2 f_c - f_n = (100 \times 2) - 8 = 192\text{MHz}$$

The drawback is a lower output that is only -32dBm at 108MHz. Easier removing of the “bad” alias or better output power: what is the choice!

Table 1: Other frequencies present at the output of a 28MHz DDS

Frequency MHz	Output dBm
28	-14
52	-20
80	-66
108	-28
132	-30
160	-52
188	-30
212	-30
268	-34

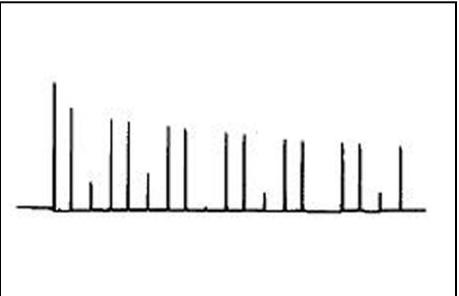


Fig 3: The output spectrum of a 100MHz clocked DDS. Nominal frequency : 45MHz.

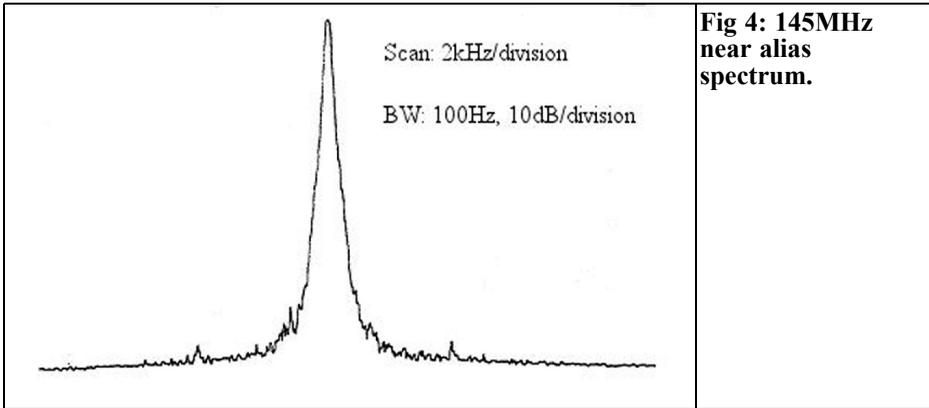


Fig 4: 145MHz near alias spectrum.

Table 2: Other frequencies present at the output of a 45MHz DDS

Frequency MHz	Output dBm
45	-10
55	-12
100	-60
145	-20
155	-20
200	-45
245	-24
255	-24
300	-60
345	-27
355	-28

3.

Another example

This method can be used to produce any VHF frequency. For example, with a 100MHz clocked DDS and a 44 to 46MHz nominal frequency, we can get a 144 to 146MHz output. See Table 2 and figures 4 and 5.

For a first approach, we can determinate the clock frequency required by dividing the desired frequency by 1.4. As shown in Fig 1, we stay in a favourable zone where the alias level is near the maximum. Too near 1.5 and the “bad” alias is

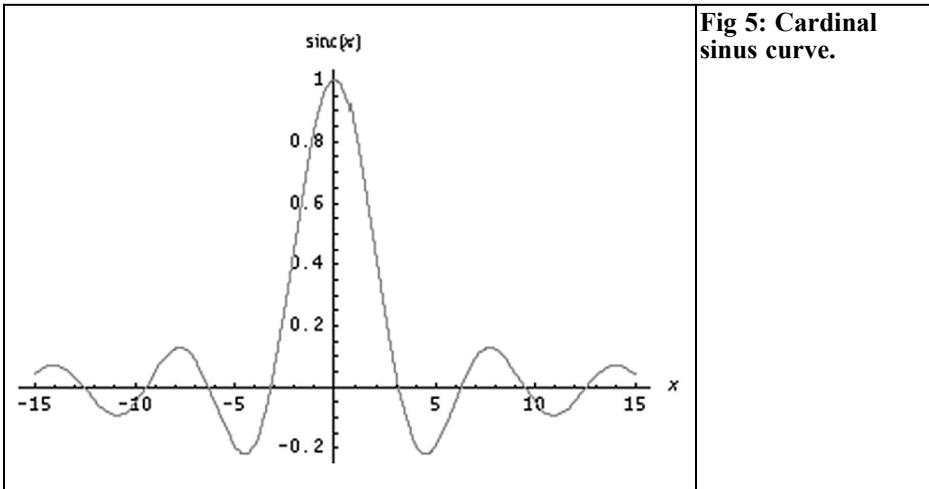


Fig 5: Cardinal sinus curve.

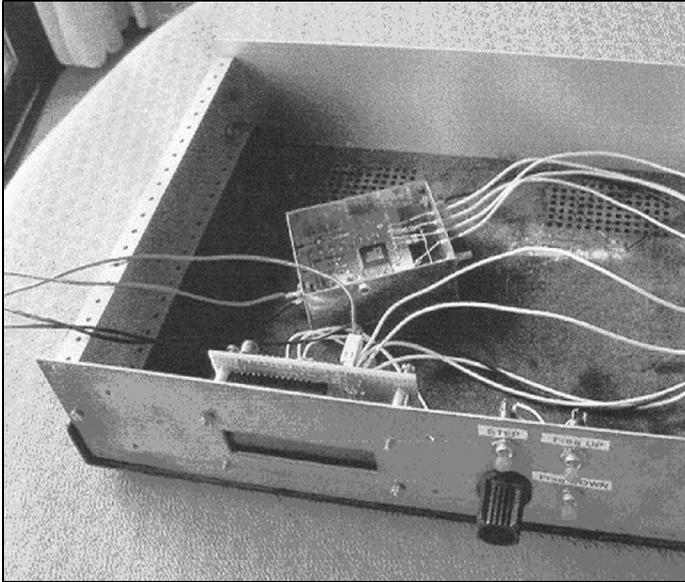


Fig 6: Picture of the F5CAU 100MHz clocked DDS.

close to the “good” one and it would be difficult to eliminate. To get higher frequencies, we have to divide by 2.4 to be in the favourable zone; nevertheless, the output will be quite low.

4.

Phase noise

Referring to [1], the alias phase noise is degraded compared to the nominal output, as the level is reduced. Further from the Nyquist limit more it is noticeable.

We also have to take into account the advantage of a direct a 144 to 146MHz signal generation instead of multiplying a 24.166MHz by six. That multiplication induces a phase noise increase equal to the squared frequency ratio:

$$10 \times \log(62) = 15.6 \text{ dB}$$

Figure 4 shows the near spectrum of a 145MHz alias.

5.

Realization

The DDS module, assembled by F5CAU comprises an AD9852 and a PIC to control the frequency, the LCD display and memories. The frequency steps are from 1Hz to 1MHz. A digital encoder controls the frequency steps.

I have made several experiments to get various frequencies. I obtained consistent results with the theory and spectrum analyser curves are convincing.

Unfortunately, I am not skilled enough to cope with the very small pins on the DDS (do not forget F9HX is licensed since 1946!). So, I only use the F5CAU module and I am not able to describe one built by myself. Sorry, but you can't do the impossible! I only hope to attract attention of readers fond of exotic devices.



6.

Conclusion

It is obvious that an up-to-date DDS working with a 500MHz clock is able to deliver a VHF signal without the need of aliases. Nevertheless, it is easier to produce a VHF frequency clock (80 and 100MHz as described above) instead UHF one. Moreover, this method opens a possibility to generate UHF signal with a common DDS instead of gigahertz DDS that are still state of art devices.

If any readers know about any other similar DDS use, apart [4,5], please let me know (agit@wanadoo.fr). I'll take it!

7.

Appendix

The frequency envelope of a DDS is given by one function called cardinal sinus:

- $\sin c(x) = \frac{\sin x}{x}$ (not normalised form)

When the variable is null, the cardinal sinus is undetermined 0/0. So, by derivation, we can find the limit that is 1.

That function is shown in Fig 5.

In practice, we cannot have negative values for both frequency and magnitude. So, the actual curve is given by

- $|\sin t| = |\sin \pi t/\pi|$ with $t > 0$

which correspond to Fig 1.

8.

References

[1] A Technical Tutorial on Digital Signal Synthesis, ANALOG DEVICES - <http://www.analog.com/en/DCcList/0,3090,770%255F%255F65,00.html>

- Section 2: Understanding the sampled output of a DDS Device
- Section 10: Using DDS Images as Primary Output Signals in VHF/UHF Applications

[2] Multiplication division and addition of a 10MHz source to get a synthesised VHF signal, F5CAU & F9HX, VHF Communications 2/2003, pp 119 - 124

[3] A Low Budget Vector Network Analyzer for AF to UHF, DG8SAQ QEX 3/4 and 7/8 2007

[4] Using DDS Aliases to Extend the Frequency Range, Sam Wetterlin, www.wetterlin.org/sam/AD9952/MultiClockAliasing.pdf