## Memo 77

Complex to Real Conversion By Wilbert Lynn Urry Jan. 29 2008

A quadrature downconverter is used in the beam former to bring a 100 Mhz pass-band at RF down to base band. The quadrature downconverter separates the 100 Mhz bandwidth into two independent 50 Mhz quadrature components. The two pass-bands are considered the real and imaginary parts of a complex signal. Before the complex signal can be used it must be converted to a real signal. There is a well known method for separating the upper and lower sidebands about the LO into two separate 50 Mhz real signals. What is needed is a method to recover a single 100 Mhz real signal.

I ran across a very clever complex to real conversion technique while trying to research this problem on the web<sup>1</sup>. Suppose the generation of quadrature components is viewed as an encoding method. A real signal from 0 to 100 Mhz is turned into quadrature components by mixing it with a 50 Mhz sin/cos down-converter. These quadrature components will behave the same as those produced from a higher frequency.



While the in phase and quadrature phase signals are shown as having positive and negative frequencies, in reality the sidebands are folded over on themselves making them useless for analysis. The classic way of separating the sidebands is to pass one of the quadrature components through a Hilbert transform (90 degree phase shift) filter and adding or subtracting it from the other component. We currently use this method in the beam former to produce two possible 50 Mhz pass-band outputs.



The above system takes a 100 Mhz bandwidth signal sampled at 200 Mhz and mixes it with 50 Mhz sampled sin and cos LO sinewaves. The sampled sin and cos have values of +1, 0, -1, and 0. They can be replaced by simple switches. The quadrature mixers can be replaced by a multiplexer.



In order to align the 100 mega-samples of the I and Q signal paths so that they appear at the same time a 5 nsec delay element is introduced.



The original design given in the reference provided very little in the way of an explanation. Once the answer is provided it seems obvious. I have seen many elaborate ways to do this, at least one of them patented, that it can be done using little more than a simple switch is startling. The original description and figure is included.

Complex to real transformation is performed translating the output of the sharp ?lter in frequency by 1/4 of the sample frequency. If  $C_n$  is the ?lter output at sample n, the real signal  $S_n$  is given by  $S_n = \text{Re}(C_n \exp(2? \text{ in}/4))$ . The exponential assumes cyclically the values (1, -i - 1, i), i.e. has only integer real or imaginary components, and can be simply implemented by the circuit shown in ?g.11. The circuit selects alternatively the I and Q output, and thus only alternate values need to be computed by each ?lter branch.

I output



Figure 11: Complex to real converter. I and Q samples from the complex ?Iter are fed with both signs to a 1:4 selector. The input signal must have a total bandwidth of half the useful range (from  $-f_s/4$  to  $+f_s/4$ ). Output has the same data rate and total bandwidth, translated to positive frequencies only (from 0 to  $+f_s/2$ ).

 $^1\,\text{G}$  Comoretto "Design of a FIR filter using a FPGA" Osservatorio Astrofisico di Arcetri Report N° 5/2002 revision 2.1 Firenze, Nov. 2002