VSRT MEMO #001

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To: VSRT Group
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Subject: Preliminary concept for VSRT image processing

The VSRT Low Noise Block downconverter feeds (LNBs) illuminate 45 cm diameter offset parabolic dish. If the LNBs has a 60 K system temperature and 50% aperture efficiency the Sun at 12 GHz (~ 4×10^6 J) should approximately triple the noise power. The first exercise for a student would be to make "single dish" measurements by connecting a single LNB to the set-up shown in Figure 1. With 2 LNBs connected we have the set-up for a "single baseline" interferometer. With a single baseline only the magnitude of the visibility function or "fringe amplitude" can be measured as it is not possible to separate the fringe phase from the local "free running" oscillator phase. However, with 3 LNBs the closure phase can be measured and with 4 LNBs (limited only by the number of inputs on the power divider) there are 6 baselines, and 3 independent closure phase triangles.

Correlation processing is accomplished by squaring the sum of the LNB outputs, to obtain the total power digitizing the power and extracting the fringes from the Fourier transform of the power. The fringes from each baseline appear as spectral features or "spectral lines" with a frequency equal to the difference of local oscillator frequencies for this baseline.

Examine the mathematics:

The power, p, from the combiner is given by

$$p = \left| \sum_{i=0}^{N-1} g_i \left(n_i + s_i \right) \right|^2$$

where i = antenna index

N = number of outputs in sum

g_i = voltage gain for the i^{th} LNB

n_i = receiver noise

s_i = noise from Sun

$$p = \sum_i \sum_j g_i g_j n_i n_j^* + g_i g_j s_i s_j^*$$

if we assume that the receiver noise is uncorrelated and $|n_i|^2 = 1$ then

$$p(t) = \sum_i g_i^2 \left(1 + |s|^2\right) + \sum_i \sum_{j>i} 2 g_i g_j V_{ij} |s|^2 \cos\left(\phi_{ij} + \Delta_{ij} t\right)$$

where Vij = magnitude of normalized source visibility on baseline ij

ϕ_{ij} = visibility phase

$\Delta_{ij} = 2\pi\left(f_i - f_j\right)$ = local oscillator frequency difference

The fringes can be “seen” in the sine wave of the digitized output. For system tests in the class room 2 LNBs can be pointed at each other or at a common noise source. When LNBs are pointed at each other a component of the noise from the Low Noise Amplifier (LNA) is radiated from one LNB into the other.

The digitizer is a USB 2.0 video frame grabber. The units contain 2 ASICS the first is a Phyillips SAA7113 whose documentation is “open” and a complete data sheet is available. The second ASIC is an Empia EM28XX where xx=20 or 60. The Empia documentation is not open and cannot be obtained from the web. However, several groups are “reverse engineering” this chip and quite a bit of information is available. The EM28XX accepts the digital data from the SAA7113 and makes it available via USB isochronous (EM2820 and EM2860) or bulk (EM2820 only) data transfers. The EM28XX is designed for the TV fame which has “gaps” in the data during the horizontal blanking. While, in the future, it may be possible to eliminate these gaps their presence only reduces the effective integration available.

The normalized visibility of the Sun can most easily be obtained by measuring the strength of the signal at $\left(f_i - f_j\right)$ Hz with the dishes as close together as possible. With a baseline of 0.5 m the fringe spacing is about 3˚ making the Sun an unresolved point source.

Alternatively the gains can be measured using a volt meter to measure the D.C. output of the detector. The video frame grabber chip (SAA7113) is a.c. coupled on its input so that the total power cannot be measured directly without modification to the circuit. Absolute measurement of the total Sun flux might be measured by using a calibrated noise source coupled to an antenna of known gain. This artificial source calibration method will require some development.

With 3 or more LNBs the phase of the fringes can be used by going around a triangle of baselines. In this case, we get a “closure’ phase for which the local oscillator phases cancel.

The phases can be determined from taking

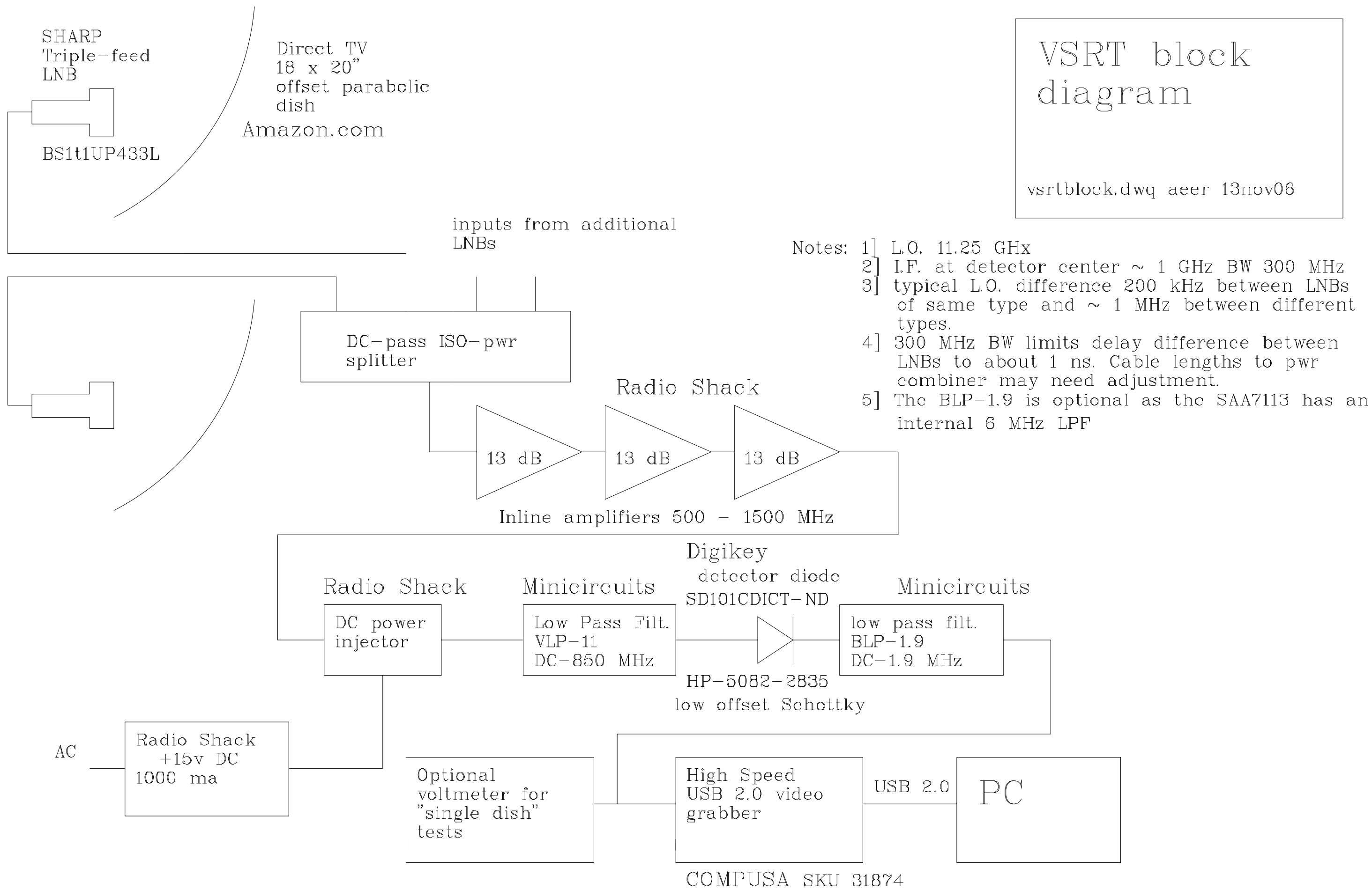
$$\phi_{ij} = a\tan 2\left(-\mathrm{Im}, \mathrm{Re}\right)$$

where Re and Im are the real and imaginary components of the FFT at the frequency for which the fringes appear for this baseline. The closure phase is given by

$$\phi_c = \phi_{01} + \phi_{12} - \phi_{02}$$

for the triangle 012. But there is a sign ambiguity in the determination of the fringe phase from atan2 above. This is because we only know the magnitude of the difference of L.O. frequencies. We can however put the L.O. frequencies in order with only a single sign ambiguity for the ensemble. With the L.O. frequencies in order we should get a closure phase of zero or 180˚ for a symmetric source but when the source becomes asymmetric (i.e. like the Sun with an off center spot) we will need to determine the correct order of L.O. frequencies (i.e. do they go up or down in frequency) to get the correct sign for the closure phase.

Once determined, for a given setup, this choice shouldn't change. For one brand of LNB (Sharp) the sign of the difference of the L.O.s of 2 LNBs could be determined by heating one LNB which results in a decrease in the L.O. frequency. Another method which might work for all LNBs is to interrupt and reconnect the power to a given unit. All LNBs I have tested have L.O.s which start high and rapidly (with 1 second) drift lower.


SHARP
Triple-feed
LNB
BS1t1UP433L
Direct TV
18 x 20"
offset parabolic
dish
Amazon.com
VSRT block
diagram
vsrtblock.dwq aeer 13nov06
inputs from additional
LNBs
DC-pass ISO-pwr
splitter
Notes: 1] L.O. 11.25 GHx
2] I.F. at detector center ~ 1 GHz BW 300 MHz
3] typical L.O. difference 200 kHz between LNBs of same type and ~ 1 MHz between different types.
4] 300 MHz BW limits delay difference between LNBs to about 1 ns. Cable lengths to pwr combiner may need adjustment.
5] The BLP-1.9 is optional as the SAA7113 has an internal 6 MHz LPF
Radio Shack
13 dB
13 dB
13 dB
Inline amplifiers 500 - 1500 MHz
Digikey
detector diode
SD101CDICT-ND
Radio Shack
DC power
injector
Minicircuits
Low Pass Filt.
VLP-11
DC-850 MHz
HP-5082-2835
low offset Schottky
Minicircuits
low pass filt.
BLP-1.9
DC-1.9 MHz
AC
Radio Shack
+15v DC
1000 ma
Optional
voltmeter for
"single dish"
tests
High Speed
USB 2.0 video
grabber
USB 2.0
PC
COMPUSA SKU 31874