Callisto as a Wideband Down-Converter

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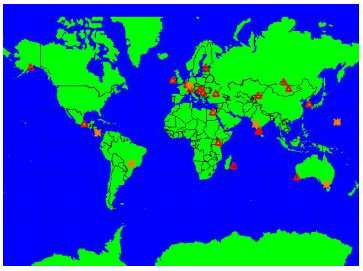
Abbreviations in this article:
EME: Earth-Moon-Earth
IF: Intermediate Frequency
PC: Personal Computer
RF: Radio Frequency
SAW: Surface Acoustic Wave
SDR: Software Defined Radio
UHF: Ultra-High Frequency
VHF: Very High Frequency

Introduction

In the Society of Amateur Radio Astronomers (SARA) journal, *Radio Astronomy*, Christian Monstein described the e-CALLISTO solar radio spectrometer network and a simple modification of the CALLISTO Receiver for operation as a narrowband (~300 kHz) single-frequency down-converter that works as a frontend to a software defined radio (SDR) [monstein]. In the current article I will describe a modification that allows the CALLISTO Receiver to operate as a wideband down-converter.



When modified as a wideband down-converter, the CALLISTO Receiver provides a 10.7 MHz intermediate frequency (IF) output with a bandwidth of about 7 MHz. The new IF output may be connected to any software defined radio (SDR) capable of being tuned to 10.7 MHz and able to process that bandwidth. Two SDRs with this capability are the RFSpace SDR-14 and NetSDR (http://www.rfspace.com/) but there are others. The IF output also may be connected to a narrowband SDR, such as the RFSpace SDR-IQ or an SDR that uses a PC soundcard, but signal processing bandwidths will be much less. In the case of the SDR-IQ, the processing bandwidth is 190 kHz, and PC soundcards are limited to 48 or 96 kHz.

Applications

The modified CALLISTO Receiver can be used in many applications including observing satellites at very high frequencies and ultra-high frequencies (VHF/UHF) to derive Doppler-information., receiving meteor trail reflections and echoes from the Moon or satellites related to space radars and amateur radio Earth-Moon-Earth (EME) transmissions on 6 m, 2 m and 70 cm wavelengths, participating in VHF-SETI activities, and observing VHF/UHF solar radio bursts with extremely high frequency resolution.

Frequency conversion

The CALLISTO Receiver is a superheteroydyn (superhet) radio receiver that covers the frequency range from 45 MHz to 870 MHz (for a tutorial on how a superhet radio works, see [radio-elec]). When used as a down-converter in front of an SDR, the CALLISTO Receiver effectively expands the tuning range of the SDR for signal processing purposes.

The modified CALLISTO Receiver operates at a single center frequency within its operating range. For example, the receiver could be tuned to 610.0 MHz. The RF frontend in the receiver has a bandwidth of around 7 MHz, as determined by the surface acoustic wave (SAW) filter built into it, so the tuner actually is working over the frequency range of 606.5 to 613.5 MHz. When the center frequency is converted by the tuner's internal mixer to an intermediate frequency (the CALLISTO Receiver's 1st IF), the bandwidth is retained. The tuner is connected to a 2nd mixer in the receiver with an IF output frequency of 10.7 MHz (2nd IF). In our example, the RF input frequency 610.0 ± 3.5 MHz appears at the 2nd IF output as 10.7 ± 3.5 MHz.

Wideband Modification

The wideband modification consists of tapping the output of the 2nd mixer just ahead of the 2nd IF bandpass filter (figure 1). The mixer output includes the 10.7 MHz intermediate frequency plus other mixing products such as the 2nd oscillator frequency and its harmonics. A lowpass filter is used to eliminate undesired mixing products prior to connection to the SDR.

Schematically, the modification is quite simple (figure 2). The wideband modification requires only a few passive components, a lowpass filter, a short piece of coaxial cable (figure 3) and a BNC-connector mounted on the front or rear panel of the CALLISTO Receiver (figure 4). All components can be mounted inside the receiver (figure 5).

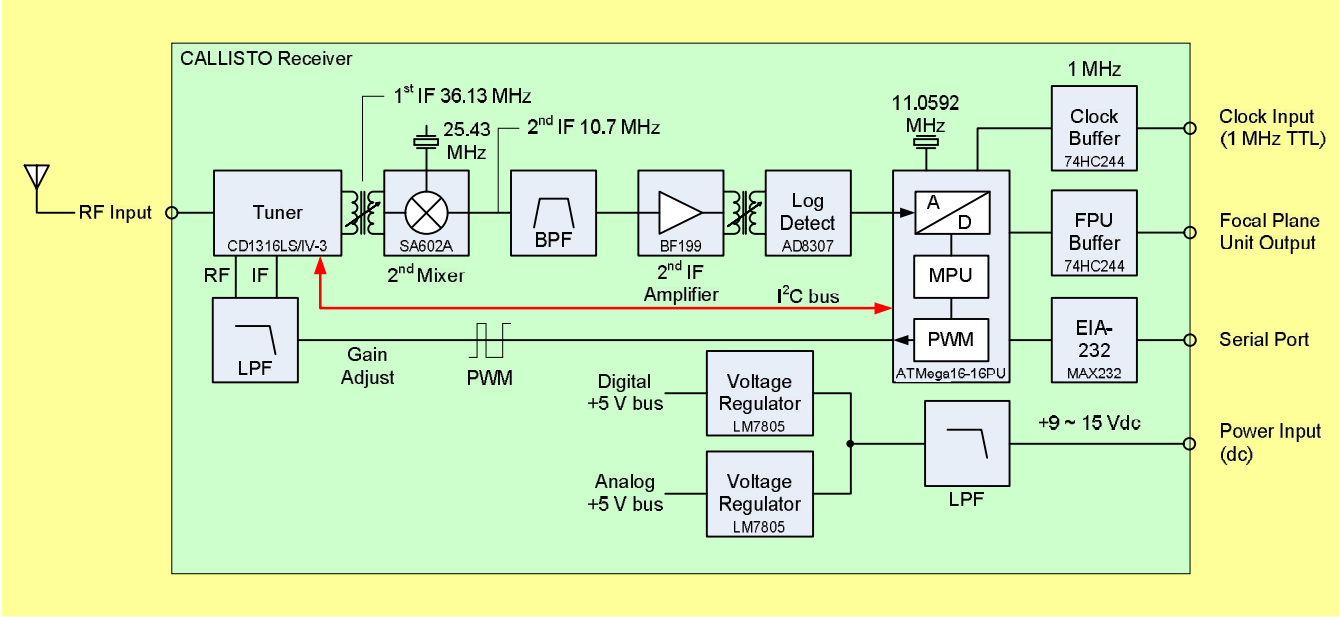


Figure 1 ~ Block diagram of the CALLISTO Receiver showing modifications, one wideband at the output of 2nd mixer – the subject of this article – and the other narrowband at the secondary of the 2nd IF output transformer.

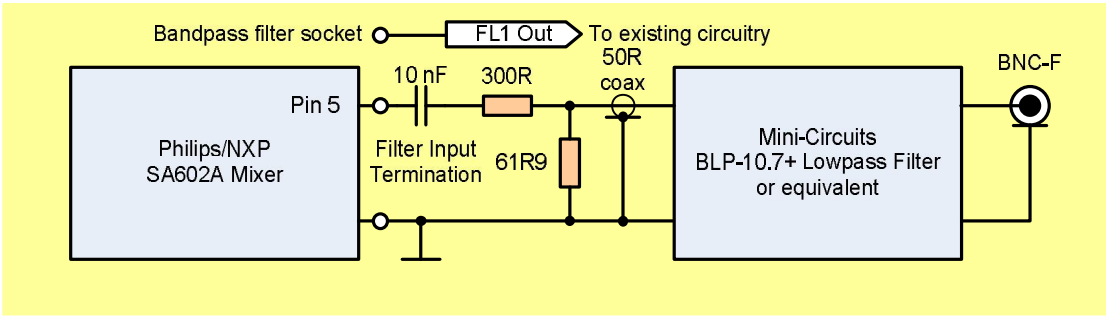


Figure 2 ~ Schematic of wideband modifications. The resistive divider provides impedance matching and the capacitor provides dc isolation. The lowpass filter eliminates undesired mixing products. A Mini-Circuits connectorized filter (http://www.minicircuits.com/pdfs/BLP-10.7+.pdf) is shown but any filter with comparable characteristics may be used. See text for discussion of the bandpass filter socket.

Figure 3 ~ Components required for the wideband down-converter modifications. In my experimental radio, I used pluggable interfaces and a commercial lowpass filter because it was available in my lab. A home-made filter may be used but the IF output response may differ from that shown later in this article. The cost of the parts shown here is about US$40.

Figure 4 ~ Panel modifications of a CALLISTO Receiver showing the BNC connector added to the rear panel to the right of the Clock Input connector. This connector also can be used with both the wideband and narrowband modifications.

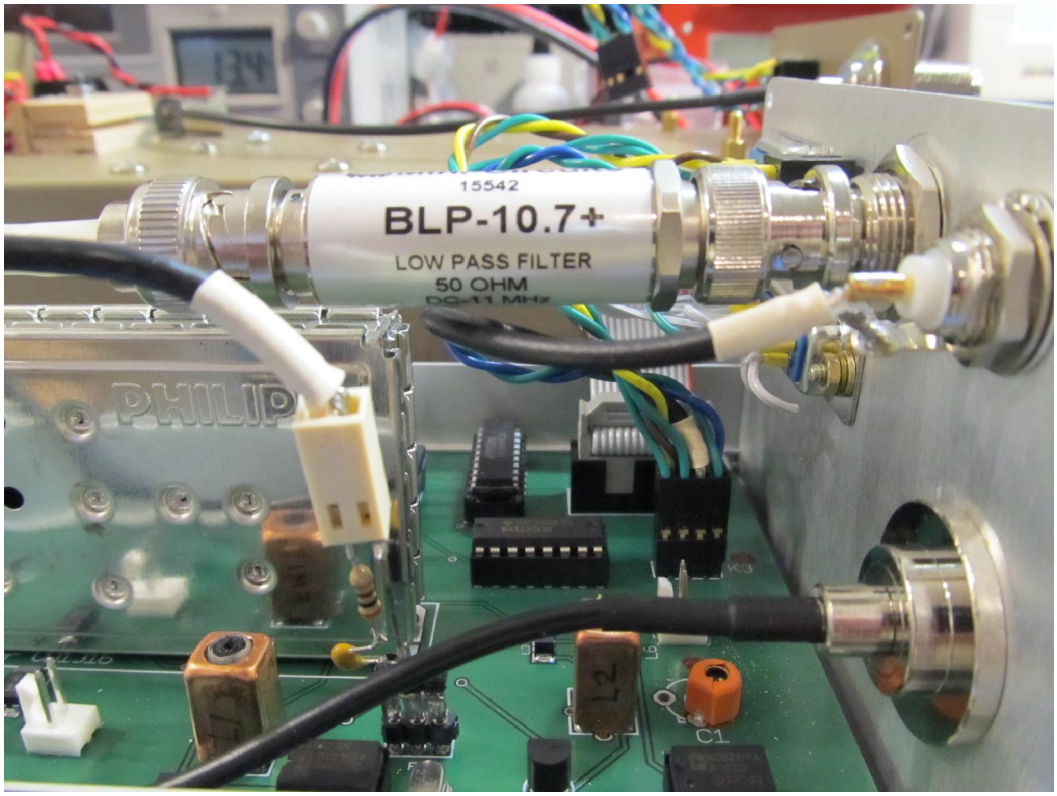


Figure 5 ~ The interface circuit shown just to the left of center is plugged into a 3-terminal socket, which I installed to allow the original 2nd IF bandpass filter to be reinstalled. The lowpass filter for the down-converter is at the top of the picture; it plugs into a bulkhead-type BNC-F to BNC-F feed-through connector on the rear panel. The small connectorized coaxial cable between the filter and interface circuit also can be used with the narrowband down-converter modification described in Christian Monstein's article by installing a 2-pin header on the PCB (partially visible behind the lower coaxial cable in the picture).

For experimental purposes and to allow the CALLISTO Receiver to be re-used in its original form, I installed a 3-terminal single-inline socket for the original bandpass filter FL1. This way I could remove the bandpass filter and plug-in the impedance matching network interface and lowpass filter to use the receiver as a wideband down-converter. To return the receiver to its original setup, I simply remove the interface and replace the bandpass filter. With this setup, the wideband modification is non-disruptive and does not preclude normal operation of the CALLISTO Receiver. However, the two modes, down-converter and normal, cannot be used simultaneously. The overall response, or transfer function, of the down-converter is quite linear (figure 6). The gain of the CALLISTO Receiver from the radio frequency (RF) input port to the wideband IF output port is adjustable through software and at maximum setting exceeds 40 dB.

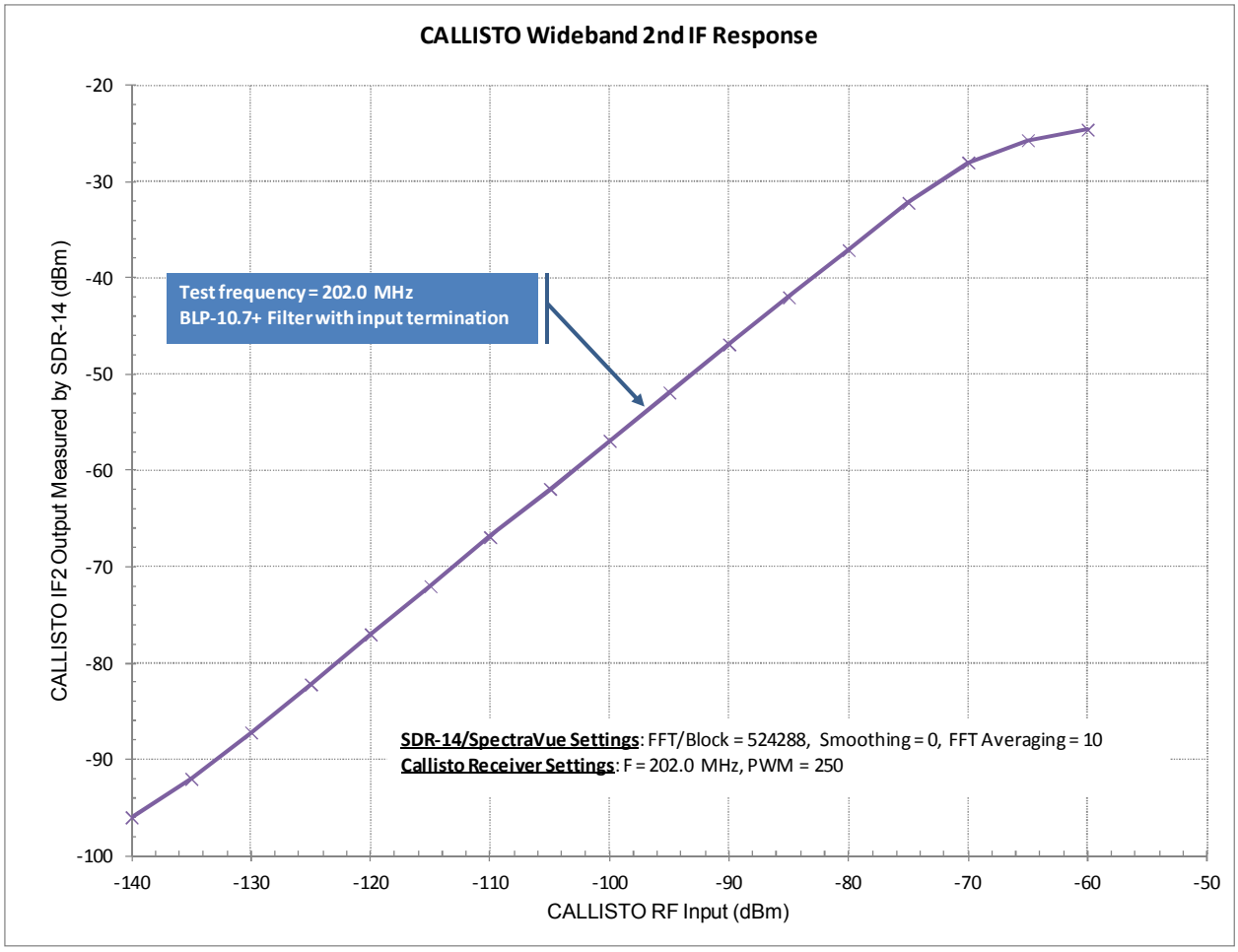


Figure 6 ~ Overall transfer function of CALLISTO down-converter. The x-axis is the RF output power from the RF signal generator applied to Callisto RF input port. The y-axis displays the 2nd IF output power (SDR-14 RF input power) as measured by the SpectraVue software. The response is linear over an input power range of approximately -135 dBm to -70 dBm.

Software control

To use the CALLISTO Receiver as a wideband down-converter, its filtered 2nd IF output signal is connected to the RF input of an SDR via a 50 ohm coaxial cable (figure 7). The frequency and gain of the CALLISTO Receiver is controlled by the Simple software application as described in Christian Monstein's article (figure 8).

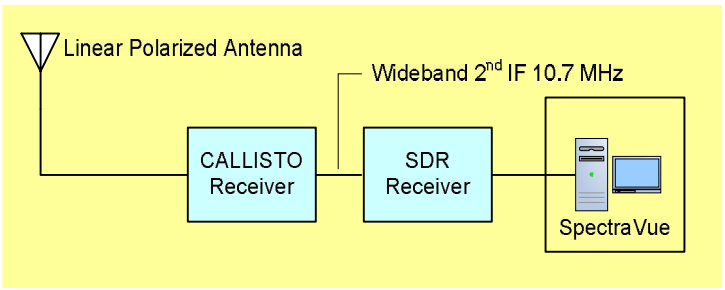


Figure 7 ~ CALLISTO down-converter connections. The SDR is operated with its normal software.

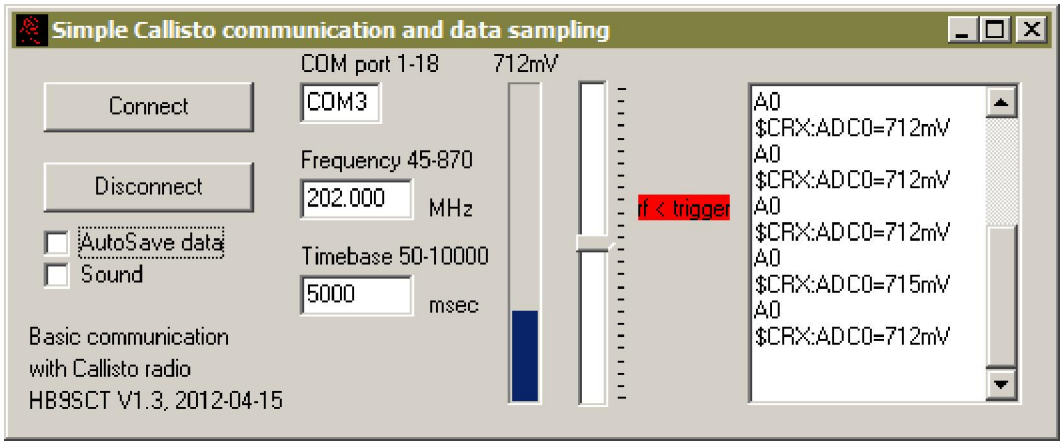


Figure 8 ~ Screenshot of the Simple V1.3 software tool with a frequency setting of 202.0 MHz. Simple originally was designed as a receiver alignment and test aid but has evolved into a more generalized frequency control tool.

The SDR is controlled by its own software, which is used to set the SDR center frequency to 10.7 MHz and the bandwidth to the desired range (figure 9). I have used the SDR-14 with SpectraVue (http://www.moetronix.com/), Radio-Sky Spectrograph (http://www.radiosky.com/) and SDR-Radio (http://sdr-radio.com/), and I have used the NetSDR with SpectraVue and SDR-Radio. If you use a narrowband SDR with a PC soundcard, there are many software choices.

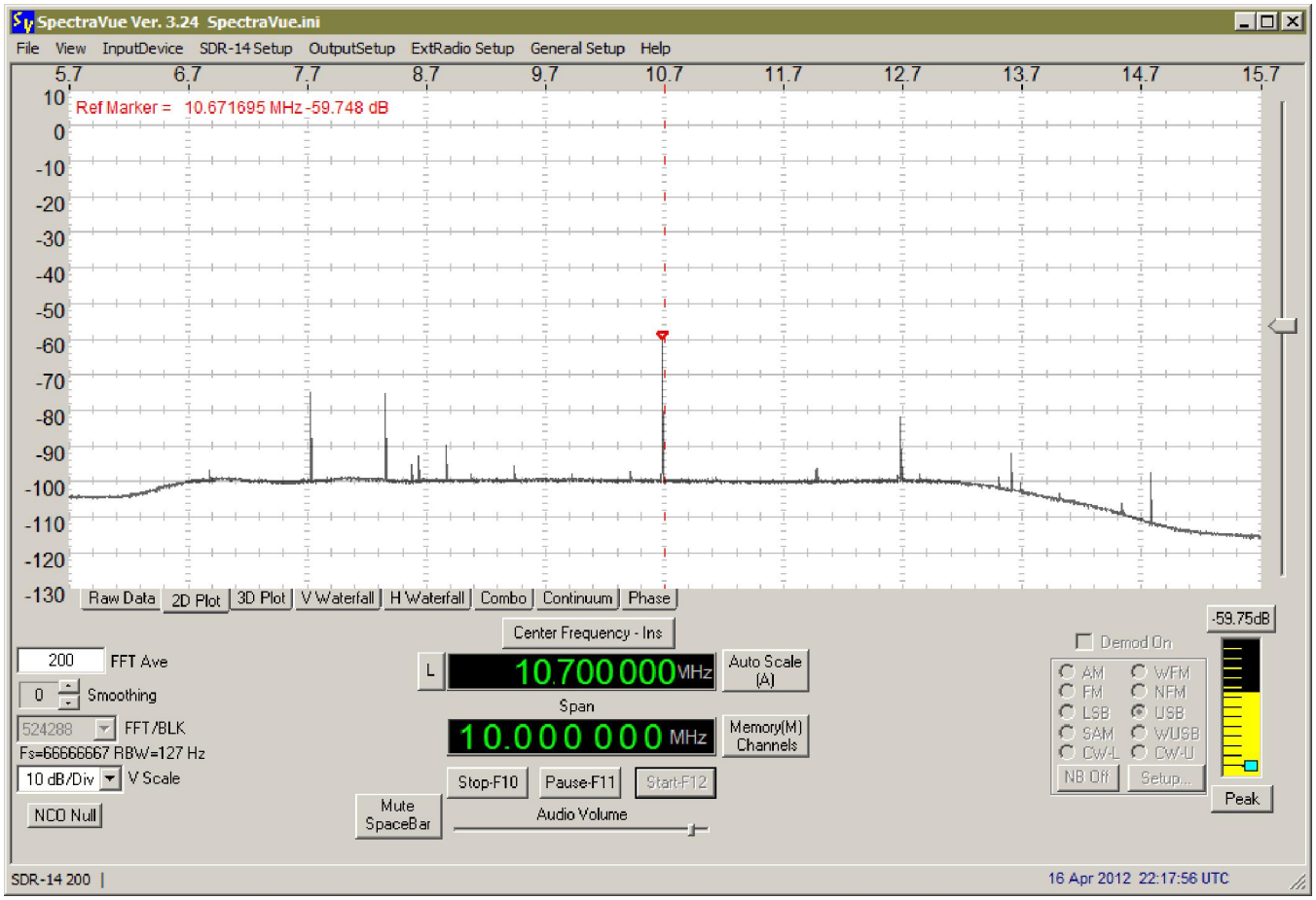


Figure 9 ~ CALLISTO Receiver 2nd IF output spectrum as seen on SpectraVue with SDR-14 tuned to 10.7 MHz center frequency and 10 MHz bandwidth. The IF output spectrum, which is shown by the slight hump in the background noise,

ranges from about 6.7 to 13.7 MHz. The CALLISTO receiver was tuned to 202.0 MHz and connected to an RF signal generator tuned to the same frequency and with an output level of -100 dBm. This carrier is indicated by the center spike with (red) triangular peak marker.

Conclusions

The CALLISTO Receiver may be easily and inexpensively modified to work as a wideband down-converter. The modified receiver has a frequency range of 45 to 870 MHz and a bandwidth of about 7 MHz. With a software defined radio connected to the intermediate frequency output, celestial emissions or signals within that bandwidth may be analyzed through the SDR signal processing software.

References

[monstein] Monstein, C., Callisto as a Programmable Single-Frequency Down-Converter, Radio Astronomy, March-April 2012.

[radio-elec] Radio-Electronics, The Superhet or Superheterodyne Radio Receiver, http://www.radio-electronics.com/info/rf-technology-design/superheterodyne-radio-receiver/basics-tutorial.php