Bidirectional Low Frequency Transverter (Bi-LIF) computer interface for demodulation and modulation of radio signals

Introduction:

The concept of a Bi-LIF (Bidirectional Low Intermediate Frequency) transverter and MDSR (Modulation –Demodulation Software Radio) was developed to provide a cost effective and easy to use interface between a computer's soundcard and a transceiver. Most amateur radio operators already own a computer and a radio and the Bi-LIF connects the two together at the IF level. This allows a software application that uses a DSP (Digital Signal Processing) synthesizer engine, which was developed in Visual Basic and Java to modulate/demodulate the out/incoming IF. All the results and parameters of th transceiver can be displayed on the computer monitor. In receive mode, the demodulated audio can be heard in the computer's headset. In transmit mode the headset's microphone is used as the input device. Since all this is done in software, it is conceivable that all types of digital modulations and demodulations can be performed in the computer and then sent to/received by the transceiver.

Objectives for the project:

- Low Cost
- Demodulation of USB, LSB, CW
- Modulation USB, LSB
- The software runs on Windows based platforms
- The soundcard is used as AD - DA converter (duplex)
- All additional hardware has to be simple and repeatable by HAMs
- Requires a minimal amount of measurement equipment for testing and alignment

Technical Specifications

Hardware (RX):

Input Frequency	455kHz (+/- 5kHz)
Input Level (max)	1mV – 20mVpp (for S9 meter reading)
Conversion Gain (max)	50dB
Output Level for S-9	0.2Vpp
LIF Bandwidth:	+/- 5kHz
LIF Frequency:	12kHz

Hardware (TX):

Input Frequency	12kHz (+/- 5kHz)
Input Level (max)	0.2Vpp
Conversion Gain (max)	0dB
Output Level	100mVpp
LIF Bandwidth:	+/- 5kHz
IF Frequency:	455kHz

Software(RX):

AM Demodulation Bandwidth:	+/- 5kHz
USB, LSB Demodulation Bandwidth:	300 – 2400Hz
CW Demodulation Bandwidth:	300 – 800Hz

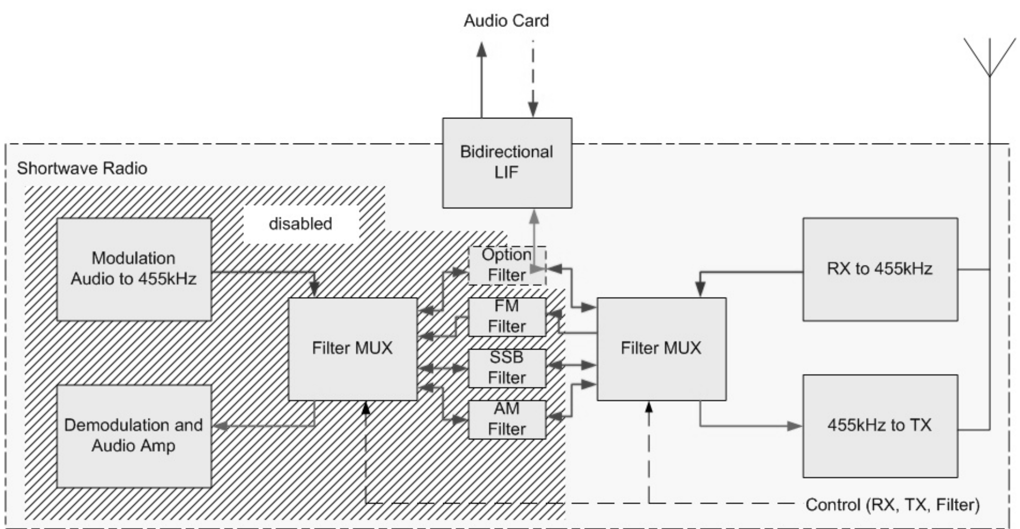
Software(TX):

USB, LSB Modulation Bandwidth:	300 – 2400Hz
CW: future option	

Using the Transceiver as a Transponder

How to extract and inject the 455kHz IF

In order for the computer to connect to the radio, a Bi-LIF (Bidirectional Low Internal Frequency) transverter is needed. This changes the radio's IF into a 12kHz incoming and outgoing audio signal which is low enough in frequency to be able to be processed by the audio card. The described method will work with any 455kHz IF radio. The radio used during the testing and development was the YAESU FT-817. ON6MU confirmed this technique on his FT-897and we have theoretically confirmed the IC-703 and 706 radios to work with this interface. (IC-706 with the 9MHz IF oscillator mod).

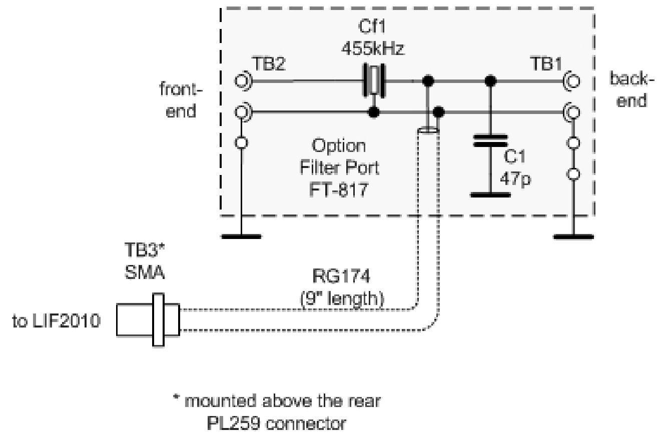


The optional filter port is used as the transponder input and output. By setting the radio to the option filter port during SSB mode and plugging in the Bi-LIF into the port, the radio is put into transponder mode. During this operation, the radio has to be set to USB modulation. This ensures that the frequency displayed on the radio is the actual RX-TX frequency. All operations except the frequency stetting, the input attenuator, the pre-amplifier and the output power setting will be done by the computer.

Caution: It is important that the TX output power is monitored during setup to prevent overloading of the finals. The nominal power rating of the radio should not be exceeded.

Option filter port extended to the rear of the radio

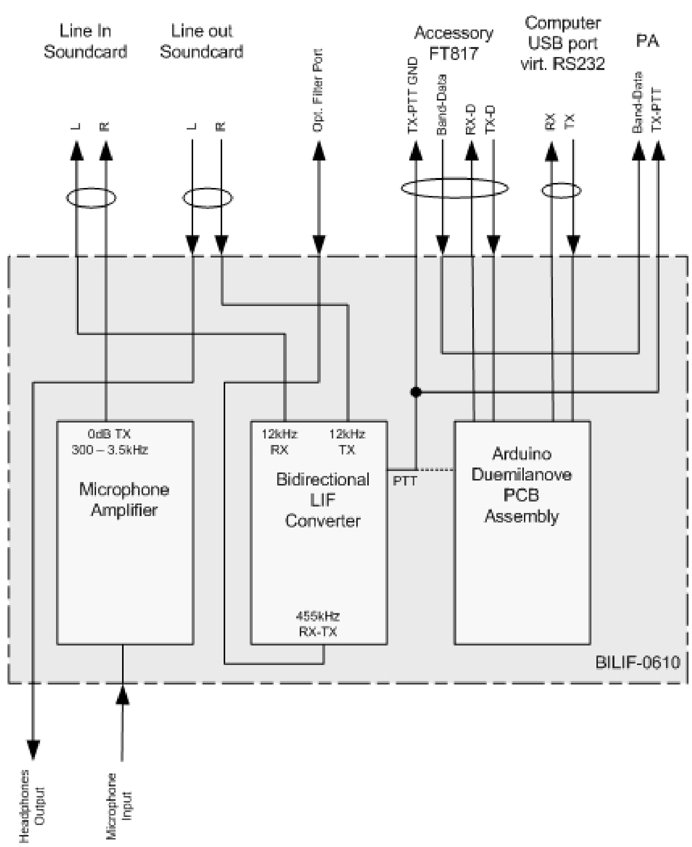
A small circuit board serves as the platform to solder the 0.075" spacing strip connector as well as a 470pF capacitor and a 455kHz filter. A small rubber cube glued on top of the PCB insulates and secures the assembly when the lid is closed. The shielded cable is RG174 and the connector on the rear wall of the radio is a SMA male, chosen for its small size. This modification does not impact the portability of the unit nor does it affect performance in any way. From here, it connects to the input of the LIF converter.



Note:
This method works for TX and RX signals. The signal flow for RX is from the transceiver to the LIF or Bi-LIF and for TX from the Bi-LIF to the option port. The transmitter will treat this signal as if it was generated internally. It will be up-converted, amplified and filtered before it goes to the antenna port, eliminating any other requirements to prevent out of band transmissions.

Conversion of 12kHz LIF (Low Intermediate Frequency)

<u>Functional Diagram of the Bi-LIF</u>



Circuit Description

TX Signal Pass

The microphone audio is amplified by +40dB by a modified HiFi AF preamp (Q1, Q2). P1 sets the amplification. The preamp is configured to only amplify 300 – 3500Hz. The signal is sent on the left line input channel to the audio card where it is digitized. The software in the computer combines the pseudo oscillator and the mic audio and creates the 12kHz digital IF signal. The data stream is sent to the sound card, converted into an analog signal and delivered to the right channel. From there, it is sent to the Bi-LIF where it is up-converted (U1) and filtered to 455kHz. P3 sets the level of the input and therefore also affects the overall gain of about -3dB (adjusted to below clipping with a 0.2Vss input). A driver circuit (Q3) amplifies the IF to a level the option filter input can process. The trim-pot (P2) on the base of Q4 is adjusted to center the IF signal. The transmitter circuit will accept this signal as a valid IF and process it the same way as if it were generated internally.

RX Signal Pass

The 455kHz signal is down-converted to 12kHz (U1), amplified, filtered (U2) and fed to the right line input channel of the audio card. U1 also provides the LO for both the RX and the TX path. The software in the computer demodulates the signal and sends it to the left output channel of the audio card. This channel feeds both sides of the headset. P1 is adjusted to prevent signal levels past S9+ from overloading the mixer.

RX-TX Combiner

The option filter operates in RX mode as an output and in TX mode as an input. To accommodate this, a diode combiner circuit unites the RX and TX signals. L1 biases D1 and D2 to +5V which opens up an unidirectional signal pass when the cathode is grounded with a 10kOhm resistor, or closes when it is reverse biased with 12V. In order to switch the RX-TX pass, Q3 operates as an inverter, enabling one or the other. In normal operation the transceiver provides the signal to set the Bi-LIF to receive (TB6 pin 2 high) or transmit (TB6 pin 2 low). The switch attenuation is about -50dB in off mode and -1dB in pass mode.

PTT and virtual RS232

To switch the Bi-LIF from receive to transmit the MDSR sends a serial command to the radio telling it to change from RX to TX or vice versa. The option port of the radio provides a TLL level serial interface as well as the “GND during TX” signal. The Arduino PCB connects via a USB port, which is more common in today’s computers than a standard RS232 DB9 connector. The Arduino chipset driver creates a virtual COM port that can be accessed with standard RS232 programming. This connection to the computer enables a set of commands to be sent to the radio to remotely control it. For simplicity and because the focus is on the software radio, further details on CAT have been omitted from this document, but can be found in the operations manual or online.

In TX mode, pin 1 of T7 is pulled to ground by the radio switching the Bi-LIF from down-converting into up-converting mode. The Arduino chip does all this without the need to be programmed. In case the radio does not provide a PTT CAT command, the Arduino can be programmed to listen to the RS232 traffic and, via the output port, a pin can be pulled low to turn the BiLIF from down converter to up converter mode.

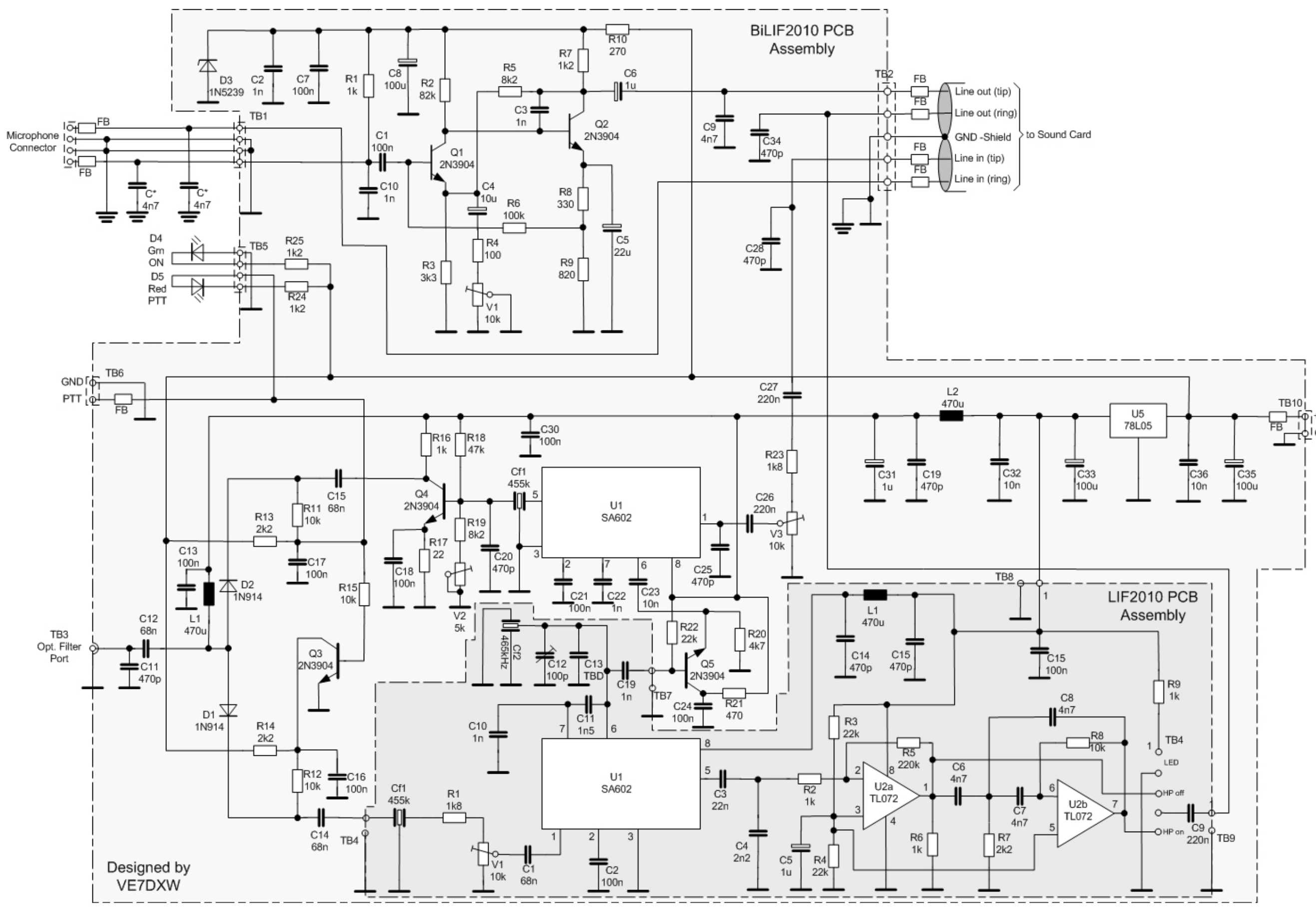
Local Oscillator 467kHz

To mix the 455kHz to 12kHz in RX mode a 467kHz oscillator signal is needed. The mixer circuit U1 on the DADP PCB also provides a built-in oscillator. Cf2 is used to stabilize the frequency and the trim capacitor (C12) is used to adjust the frequency to +/- 5Hz. The same oscillator signal is also used to provide the mixing frequency for U1. Since the signal impedance on pin 6 on U2 is high, an additional amplifier (Q5) lowers the impedance before the signal is coupled tightly to pin 6 of U1 of the BiLIF PCB.

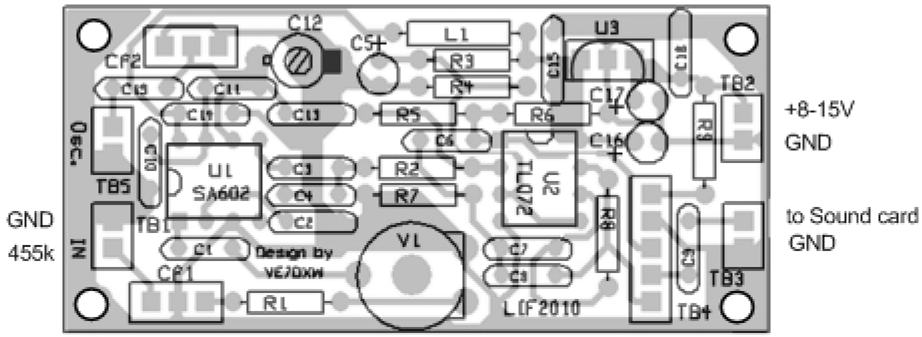
Power Supply

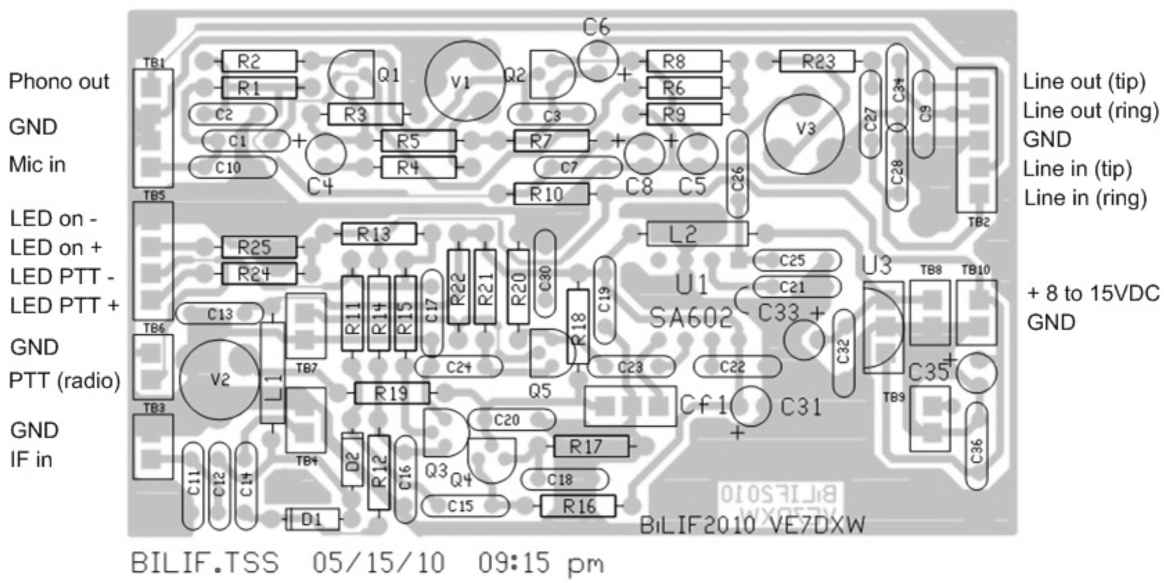
U5 provides 5V for the up and down converter as well as U4. Additional filtering is provided by the PI filters for the converter section and U4. This prevents RF and spurious emissions to enter the rest of the circuit. The microphone preamp is fed directly with 12V. R10 and D3, which stabilizes the voltage to 9V and also decouples the preamp from the supply.

Bi-LIF Schematics



The Bi-LIF PCB Layout (RX and TX are separate PCBs)

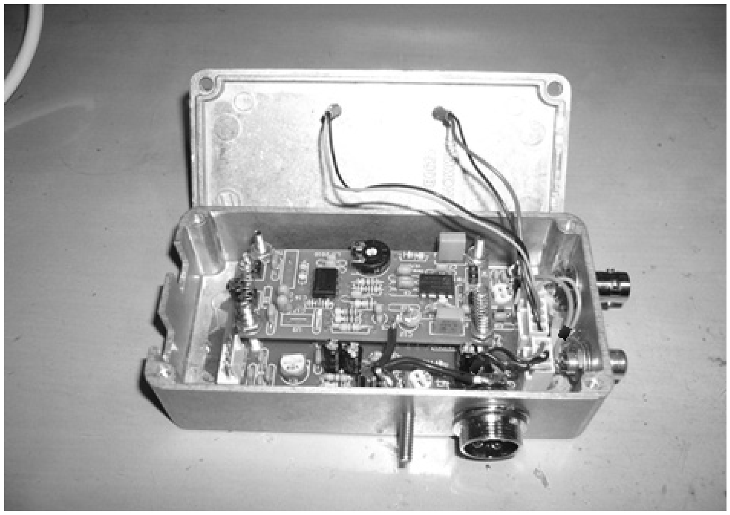




The Bi-LIF2010 in the shielded enclosure

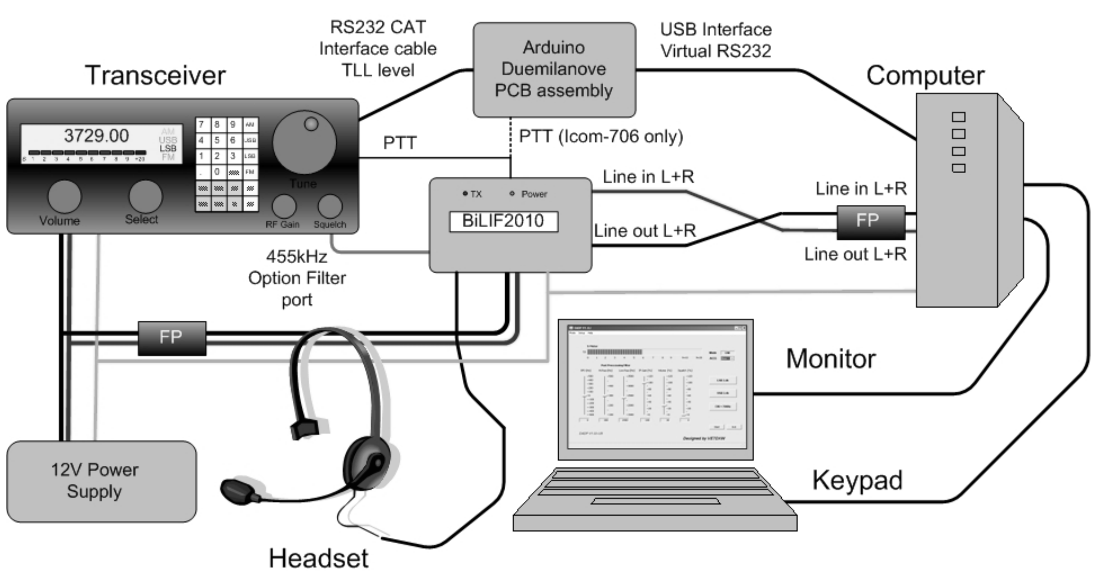
The BiLIF is made up of two PCB assemblies. The BiLIF2010 mother board contains the mic audio amplifier, power supply, filtering, the up converter with driver transistor and the combiner circuit. The LIF2010 PCB which mounts on to the BiLIF2010 PCB holds the oscillator, the down converter and the 8kHz RX high pass filter. Both boards can be seen assembled and mounted in the shielded enclosure (picture below).

To provide best performance, it is absolutely necessary to decouple all inputs with ferrite beads as shown in the schematics and to solder blocking capacitors across the connectors to the chassis ground. The top end of the screws that hold the LIF2010 are used as guides for springs to create extra ground connections to the chassis. The grounding screw connects the microphone connector and the oscillator through a thick stranded wire to the chassis ground. This is also the screw that has to connect to the station ground.



Connecting the Transceiver to the Computer with the Bi-LIF hardware

Base Station setup with BiLIF and MDSR



<u>USB Cable for CAT Interface</u>

The USB cable is a standard cable that is used to connect USB printers. This cable plugs into the Arduino controller PCB and also provides power to the controller. From there, the TLL level RS232 connects to the radio via the RX-TX serial data ports (pin 0 and pin 1 of the Arduino PCB).

<u>PTT Cable</u>

The transceiver has to provide the “PTT to GND” signal for the Bi-LIF to switch from down-converter mode to up-converter mode.

In transceivers that do not provide “PTT to GND”, the Arduino microcontroller can be programmed to provide this signal through a CAT command.

Audio Card Cables (Line in, Line out)

Two standard 3.5mm stereo shielded phono cables with a maximum length of 5m (15 ft.) have to be used; the shielding of the cables is absolutely necessary. The cables are crossed-over; Line-out from the Bi-LIF connects to the Line-in of the audio card and vice versa. For proper grounding, take a #10 gauge (1.5mm²) stranded copper grounding cable and connect the chassis of the computer to the station ground. This will actually lower any interference from the computer.

Option Filter IF in/output

The option filter IF in/output cable connects the option filter port to the combiner circuit of the Bi-LIF. As previously described, an SMA male connector has been installed into the radio. Use 6” (20cm) of shielded RG174 cable with a female SMA and a male BNC connector on the Bi-LIF side.

Ground

The Bi-LIF has to be grounded to the station ground for best performance with a short #10 gauge (1.5mm²) copper cable.

Software for the Bi-LIF hardware

At the moment there is only the RX capable software available as a free download from either the website http://users.skynet.be/myspace/mdsr or from the MDSRadio Yahoo user group http://groups.yahoo.com/group/mdsradio/ (registration is required). More information and pictures can be found at these sites.
The RX-TX capable software exists on the test-platform and is currently used as a test station .The furthest DX contact on 3W output power was made with a station in Japan (approx. 8000km from Vancouver, BC). The design of the MDSR software is currently in progress and, at this time, ON6MU (Guy Roels), K7RE (Brian Kassel) and VE7DXW (Alex Schwarz) are involved in its development. The planned release date of the MDSR software is set for later this year.

Conclusion

The development of the Bi-LIF hardware and the MDSR software was definitely a challenge and it was done on a shoestring budget. It truly lives in the HAM realm where cost is an issue. Nevertheless, the result exceeded expectations and the interface can turn a low cost radio into a high-end base station.

Acknowledgements

Even though I have put the pieces together to create the Bi-LIF, many people have influenced this design. I especially want to thank Guy Roels for encouraging me to post this development on his site and to submit it to QST, which has accepted the RX only write-up. Furthermore, I would like to thank Brian Kassel and Guy Roels for the work and time they have dedicated to create the spectrum analyzer and the DADPCAT interface. Thanks to all the amateur radio operators that have purchased a DADP2010 kit and helped to support the development. Also, big thanks to my partner, Claire, who proof reads all the documents and always listens and supports me during all my projects.

About the Author

Alex Schwarz (VE7DXW) is an advanced HAM and a graduate of the HTL, Innsbruck, Austria. He moved to Vancouver (Canada) in 1990 and has since been involved in professional communication systems (LDR trunking) and digital point to point wireless network systems. In 2005 he started work in the Biomedical Engineering Department at C&W Hospital in Vancouver. He can be reached through his email address: alexschwarz@telus.net.