Application Note
AN-23 i

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DVB-T Television Repeater

Jim Andrews, KH6HTV

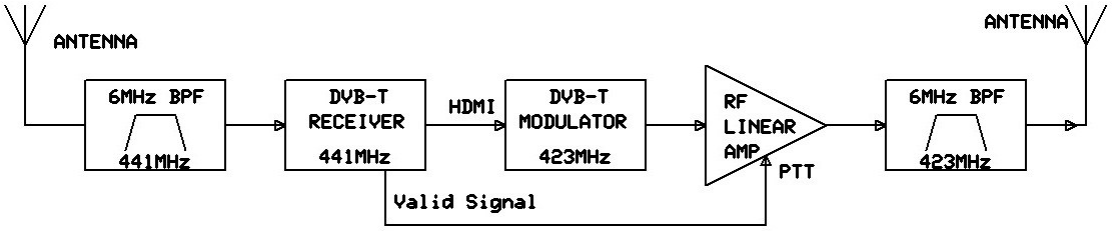

Fig. 1 A 70 cm, Digital TV Repeater, block diagram.

The FCC allows licensed amateur radio operators to transmit wide bandwidth, fast-scan, video on the 70 cm (420-450 MHz) band and all higher microwave bands. On the 70 cm band, the ARRL national band plan [1] calls for TV repeater inputs to be on Ch 60 (438-444 MHz) and outputs to be on Ch 57 (420-426 MHz) with TV simplex operations on Ch 58 (426-432 MHz). Note: These channel number designations are those used by the USA cable TV industry. Cable channels 57 through 61 with 6 MHz spacing land directly on the amateur 70 cm band. DTV channels are identified by their center frequency. Thus Ch 57 = 423 MHz.

Fig. 2 Typical, 70 cm, Inter-Digital Band-Pass Filter. Shown with top cover removed.

To build an in-band, 70 cm, Television Repeater, Fig. 1, very high selectivity, band-pass filters (BPF) are mandatory on both the transmitter and receiver. On the 70 cm band, 6 MHz channels are used and the typical spacing between the input and output is only 18 MHz. The purpose for the BPF on the receiver input is to prevent fundamental overload of the receiver's front end by the extremely strong, near-field signal from the transmitter. The purpose of the BPF on the transmitters' output is to prevent any out of band spurious spectrum from polluting the RF environment of adjacent channels and especially the receiver's near-by channel. The BPFs used are typically of the Inter-Digital BPF design, Fig. 2. Fig. 3 shows a typical swept frequency insertion loss (S_{21}) of such a filter as used for amateur TV service. Amateurs with some ordinary machine tools can roll their own such filters. Application Note, AN-22 [2] gives details about such BPFs. Application Note AN-72 [3] gives more details on determining exact filter requirements.

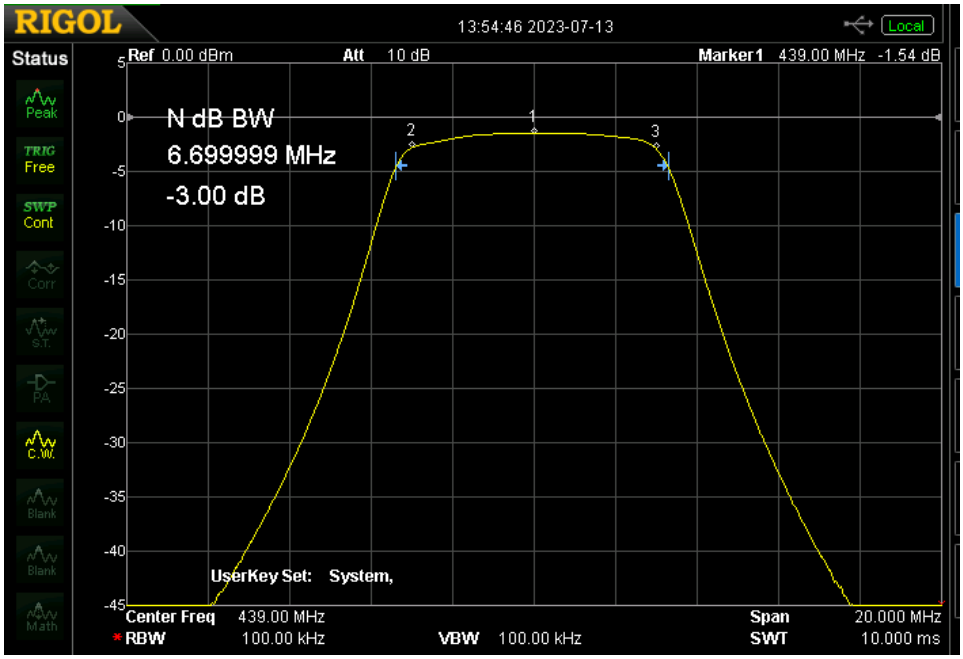

Fig. 3 Swept frequency insertion loss response (S_{21}) of a typical 6 MHz, band-pass filter used for amateur TV service. center frequency = 439 MHz, 5 dB/div & 2 MHz/div.

Most 2 m and 70 cm, FM voice repeaters with 15 kHz channels typically use a single antenna for both transmit and receive. A duplexer is typically used between the antenna and the transmitter and receiver. On 2 meters, the frequency separation typically used is 600 kHz, or a ratio of 600/15 = 40:1. On 70 cm, the frequency separation typically used is 5 MHz, or a ratio of 5000/15 = 333:1. For TV signals with channel bandwidths of 6 MHz, the ratio of transmit/receive separation to bandwidth is only 18 MHz / 6MHz = 3:1. With this close separation of only 3:1, it is very difficult to build an effective duplexer for TV repeater service. Thus, usually amateur TV repeaters do not use a single common antenna for both transmit and receive, but two separate antennas as shown in Fig. 1. If omni directional antennas are used, they should be positioned on the same supporting mast, directly one above the other so that they are sitting in the null position of each other's antenna pattern to achieve the maximum isolation between antennas. For

portable repeaters using directional antennas, there is definitely a right and a wrong way to position your yagi antennas ! See Fig. 4 below.

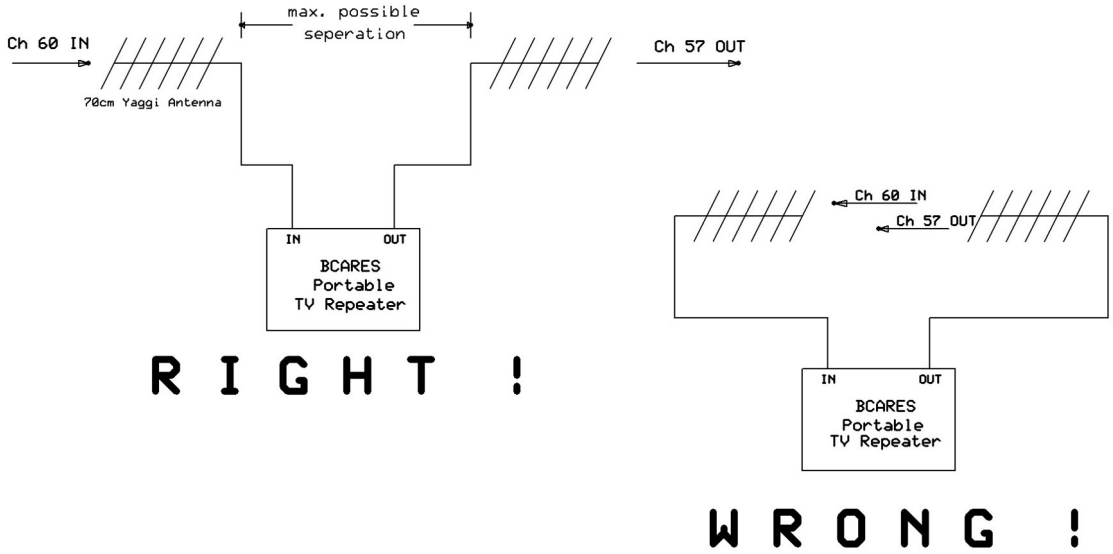

Fig. 4 Portable TV Repeater using Yagi Antennas. The secret to a repeater is high isolation between the transmitter and the receiver.

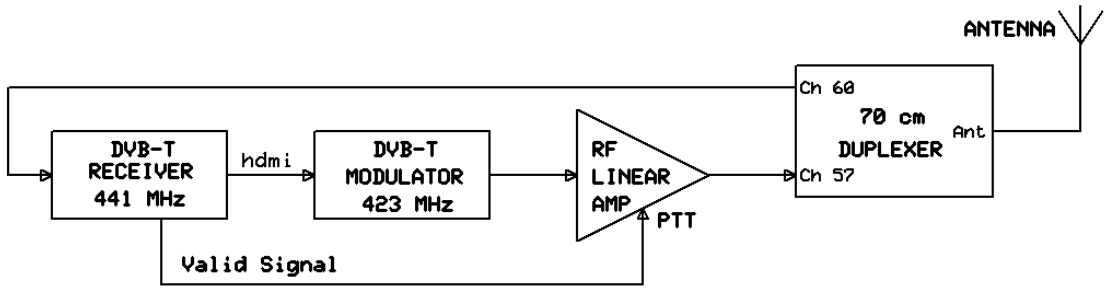

Fig. 5 An in-band Digital TV repeater built with a Duplexer

Wide band-width, close separation Duplexers for a TV repeater however are possible. Fig. 5 shows how a duplexer would be used to assemble an in-band, digital TV repeater. TV duplexers are more difficult to build, and are more costly. They serve the same function as the two band-pass filters shown in Fig. 1, but include internal cross coupling between the two filters. They thus allow the repeater to use a single antenna for both receive and transmit. A TV duplexer will not give as much isolation as the BPF & two antenna arrangement. Thus an ATV repeater using a duplexer will typically also end up requiring a set of band-pass filters. One on the receiver input and one on the transmitter output, prior to the duplexer. The two antenna arrangement of Fig. 1 is the preferred arrangement. For a crowded antenna tower situation where there is only space for a single antenna, then the duplexer solution of Fig. 5 may be the only solution. Fig. 6 shows a typical 70 cm ATV duplexer. It is a three port device. Fig. 7 shows the typical swept frequency insertion loss (S_{21} & S_{31}) of such a duplexer.

Application Notes, AN-48 [4] and AN-49, [5], give details on an actual, basic, 70 cm, DTV repeater built for either two or one antenna(s) and without or with the ATV duplexer.

Fig. 6 A 70 cm Duplexer for ATV or DTV service

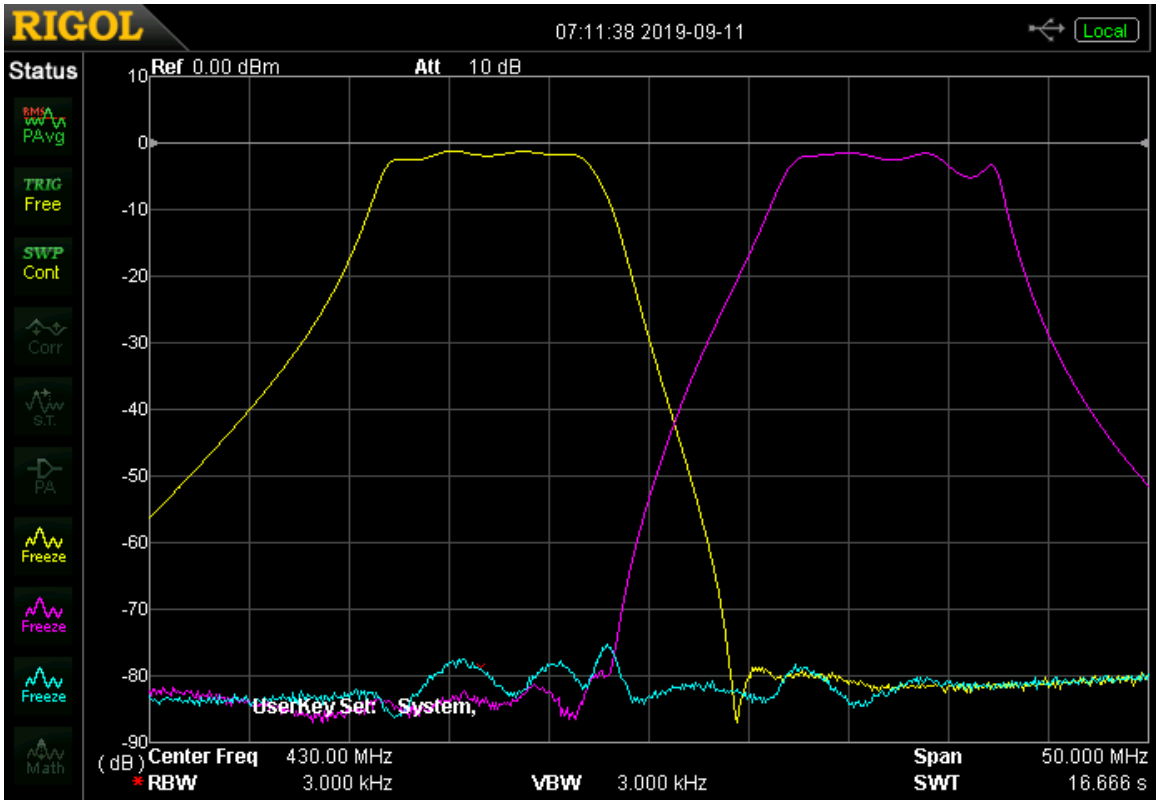

Fig. 7 Swept frequency insertion loss (S_{21}, S_{31} & S_{32})of a typical duplexer used for 70 cm amateur TV service. The lower pass band is tuned for Ch. 57 while the upper pass band is tuned for Ch. 60. 10 dB/div & 5 MHz/div, center freq. = 430 MHz, noise floor of measurement is -83dB. S_{21} = yellow trace, S_{31} = magenta trace S_{32} = cyan

CROSS-BAND TV REPEATERS: Repeaters can also be built as "Cross-Band", meaning the input and output frequencies are not on the same bands. Oftentimes, assembling a cross-band repeater is much simpler than building an in-band repeater because of the extreme separation in input/output frequencies. In some cases, the special band-pass filters can even be eliminated. Then it is a simple matter of patching the output of the receiver into the transmitter and you are on the air repeating. The simple arrangement shown in Fig. 8 could be lashed together within less than 5 minutes for an emergency DTV repeater. Simply omit the Valid Signal requirement and have an on-site control operator turn the transmitter amplifier on or off as needed.

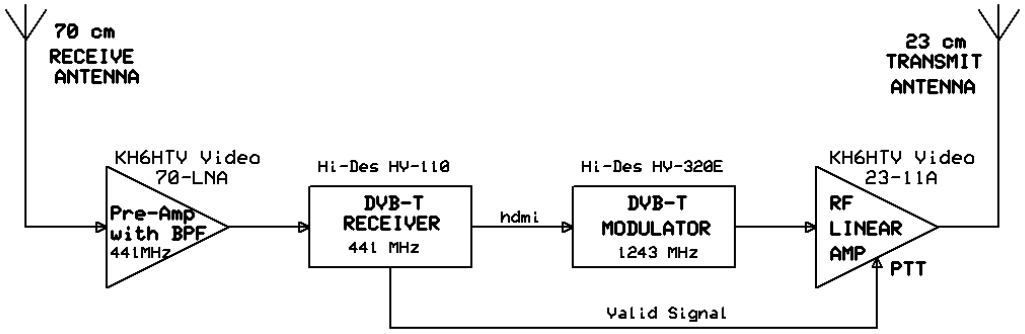

Fig. 8 Basic 70 cm to 23 cm Cross-Band DVB-T repeater block diagram using two antennas.

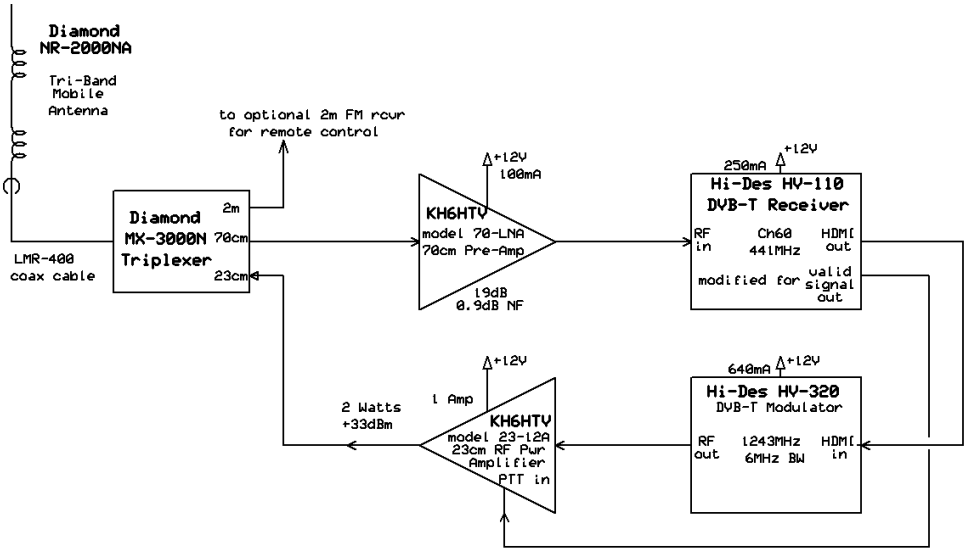

Fig. 9 Basic 70 cm to 23 cm Cross-Band DVB-T repeater block diagram using a single tri-band antenna with triplexer

A cross-band repeater is especially easy when the input frequency is on a band lower than the output frequency. If the output frequency is however on the lower band, then more care is required. One must first consider the selection of frequencies. One should especially avoid choosing frequencies where the receive frequency is on one of the harmonics of the transmitter frequency. If this is unavoidable, then extra low-pass filtering will be required on the transmitter's output.

Fig. 9 shows how to accomplish a 70cm to 23cm cross band repeater using only a single, tri-band mobile antenna. The Diamond model NR2000N is recommended for this application.

A popular cross-band repeater with several ATV repeater groups, including Boulder, Colorado, is with a 23cm input and 70cm output. Fig. 10 below shows the basic arrangement. Most all commercially available DVB-T receivers only tune up to around 950MHz at the highest where they cover the typical TV UHF broadcast bands. So DVB-T repeater builders will need to use the arrangement shown with a 23cm Down-Converter ahead of the conventional HV-110 receiver.

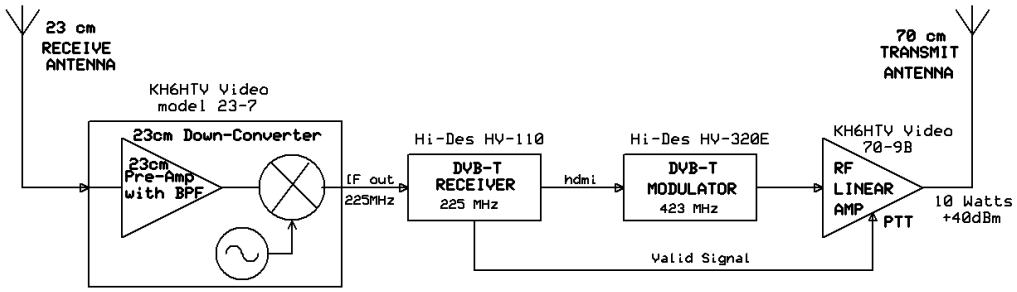

Fig. 10 Basic 23 cm to 70 cm Cross-Band DVB-T repeater
block diagram using two antennas, plus a down-converter

If transmitter power levels are kept low, the single tri-band mobile antenna with triplexer arrangement, such as shown in Fig. 9 could also be used for a 23cm to 70cm repeater.

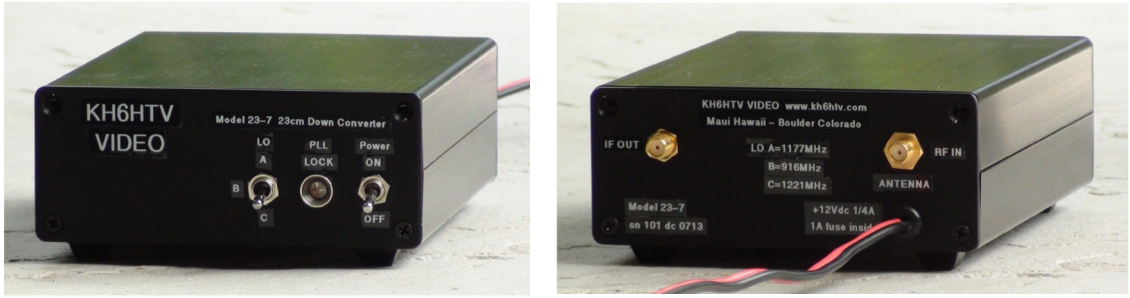

Fig. 11 KH6HTV Video model 23-7, 23cm Down-Converter, front & rear panel views

The recommended down-converter to use is the **KH6HTV Video model 23-7**. See Figs. 11 & 12. No extra preamp is required with it. The KH6HTV model 23-LNA is included inside the box along with the frequency synthesized local oscillator, and mixer.

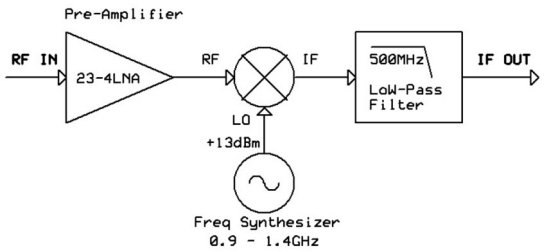

Fig. 12 23-7 Block Diagram

Fig. 13 Portable, Basic, 70 cm, DVB-T repeater built by Matt Holiday, W0DVB, for BCARES

BASIC DVB-T REPEATERs: It is a very straight forward matter to assemble a basic DVB-T repeater, especially when one uses the modulators and receivers from Hi-Des Technologies in Taiwan. The recommended DVB-T modulator is the Hi-Des model HV-320. For the receiver, use the HV-110. RF linear power amplifiers and pre-amps are available from KH6HTV Video. Fig. 13 shows one example.

I have built several Basic DVB-T repeaters for other groups. They have included both in-band and cross-band repeaters. They are documented in several application notes. See the list of references [4-8].

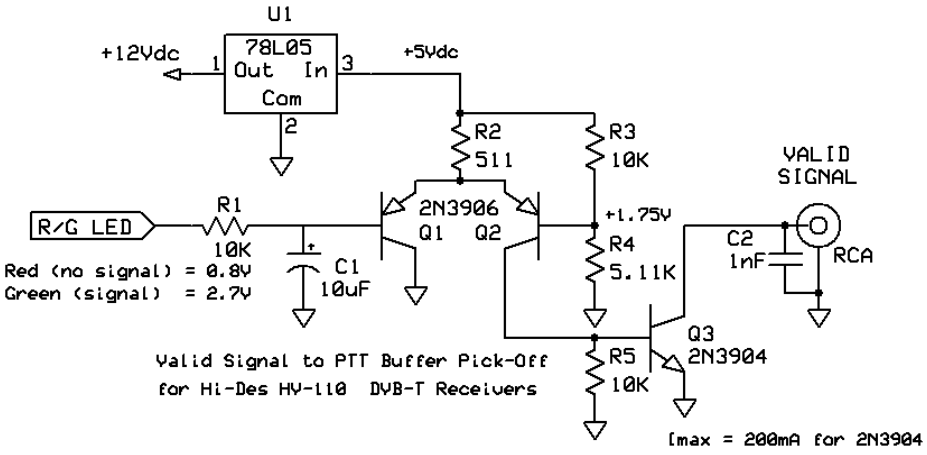

Fig. 14 Simple circuit to obtain *"Valid Signal"* from HV-110 receiver.

VALID SIGNAL: From your DVB-T receiver, you will need to have access to a Valid Signal indicator. For automatic operation of a repeater, one only wants it to be transmitting when it is receiving a valid incoming DTV signal. At all other times the transmitter needs to be disabled. Disabling is easily accomplished using the PTT (Push-To-Talk) line on the RF amplifiers. The PTT line is keyed using a logic *"Valid Signal"* from the receiver. KH6HTV VIDEO RF Linear Amplifiers are all equipped with the ability to use a PTT control line. They typically have PTT On/Off ratios of >90dB. Low PTT = RF ON, High PTT = RF Off.

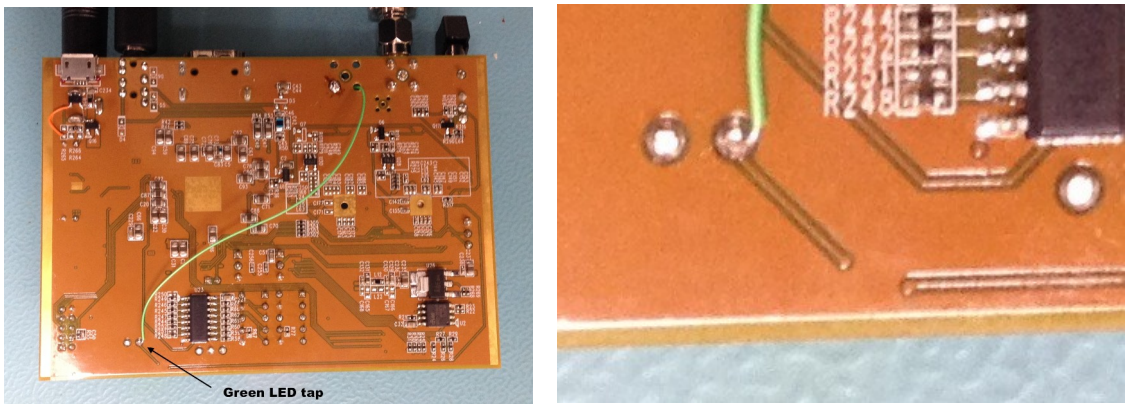

Fig. 15 View of underside of HV-110 pc board showing location of Green LED tap.

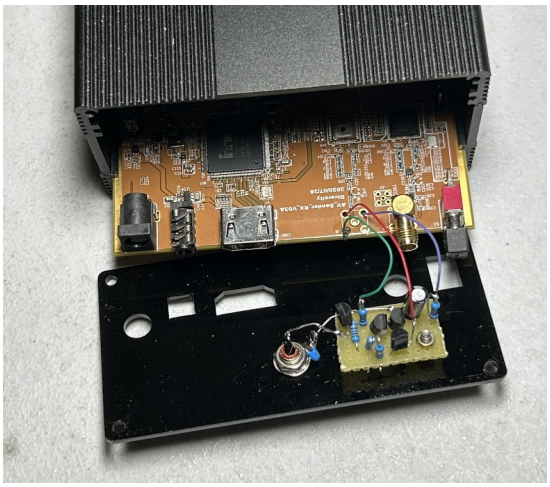

Fig. 16 Valid Circuit perf board

It is a very simple matter to obtain a *"Valid Signal"* logic signal from the Hi-Des model HV-110 receiver. The receiver has a front panel bi-color LED which indicates the status. When it is red, no signal is being received. When it is green, a valid signal is present. Thus, connecting a wire to the green LED provides the necessary *"Valid Signal"*. A simple buffer circuit is shown in Fig. 14 to convert this signal into a suitable open collector transistor switch to drive a PTT line. The capacitor, C1, is used as a low-pass filter to remove the rapid fluctuations which occur for a very weak signal at digital threshold. It adds some turn-on/off delay but improves the overall performance. Fig. 15 shows where to find the green LED tap point. Fig. 16 shows the installation of the *"Valid Signal"* circuit. Circuit was built using discrete components on a perf board. Mounted on rear panel.

FCC ID & Control: The FCC requires that all amateur radio transmissions be identified at least once every ten minutes. Using a Hi-Des DVB-T modulator, identification is automatic and we never have to do it manually or with extra circuitry. In the original design of the DVB-T system, identification of the "Service Name" was included in the outgoing DVB-T digital meta-data stream header. By programming your own call sign (such as KH6HTV) as the Service Name, your transmissions are continuously identified automatically. They will appear on the screen of a receiving station if the user press the ID button on his receiver's remote control.

The FCC also requires that a control operator maintain positive control over a repeater in the event of malfunction, or malicious usage. For a repeater in one's own home, or a manned portable repeater on an ARES operation, this is a simple matter of the operator turning off the master power switch. For an unmanned, remote base repeater, control must be maintained either via a land-line or radio link on a separate control frequency. This will necessitate the installation of additional circuitry in the transmitter's PTT line.

Other Features: Obviously, repeaters can grow to have much more exotic capabilities than the simple one shown in Fig. 13. A repeater might have multiple receiver inputs, both multiple bands, and multiple modes such as VUSB-TV, FM-TV, DVB-S, DVB-T, etc. A repeater might also have multiple transmitters on multiple bands with multiple modes. It might also be linked into a large network of other ATV repeaters, such as the ATN in southern California.

One example is the W0BTV-TVR repeater in Boulder, Colorado, Fig. 17. The original Boulder analog 70cm, NTSC, repeater started out in the late 70s. It evolved over the years with many modifications until it has reached it's current configuration. It presently is a multi-band, multi-mode repeater, both analog and digital. It is mainly a digital repeater using DVB-T modulation. It's primary transmitter is DVB-T on 70cm band (ch 57). It 's secondary transmitter is FM-TV on the 5cm band and operates as a 24/7 beacon. It has three receivers for DVB-T on the 70cm, 23cm and 3cm bands. It has remote control capability to select various functions. Full details about this repeater are in application notes, AN-51 & 53 [9& 10]. The repeater's history is in AN-52 [11]

Fig. 17 W0BTV-TV Repeater

A word of advice and caution however, before starting any ATV repeater project which involves anything more than a simple repeater, such as described above. The complexity of adding additional features goes up exponentially. What starts out simple, suddenly becomes a major engineering challenge. The simple repeater can be assembled very quickly. Anything more complex will require many, many hours/days/weeks/months of engineering time, etc. If this will be your first attempt at building a DATV repeater, then **KISS** (i.e. Keep It Simple Stupid !). You will probably be tempted to add way too many "bells & whistles" way too soon. They will follow, but make sure they are only after you have succeeded in building first a basic repeater.

If you are adding features, then a nice feature to have on a repeater is a **"Beacon"** mode. This allows a user to activate the repeater transmitter to be turned on without an incoming signal. This is very useful to allow users to optimize their home receiving stations with a known signal from the repeater. In the Beacon mode, the video source would be generated locally at the repeater site. It could be a tower mounted TV camera. Another useful source to have is a Media Player at the repeater site playing a continuous loop slide show of information about the repeater, the sponsoring club, etc. Each slide should carry the repeater's call sign for identification to be used as the sign-off trailer.

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