Application Note AN-70a

June, 2025

rev. "a", November, 2025

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23 cm to 70 cm Cross-Band, DVB-T Repeater

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Does your local ATV group need a TV repeater? Are you debating should it be an in-band 70cm repeater, or instead perhaps a cross-band repeater? Tight budget? Technically complex with lots of "bells & whistles" or KISS (Keep It Simple Stupid) ?

Fig. 1 This photo shows a proto-type 23cm to 70cm cross-band repeater All the components were assembled onto two 1U, 19", relay rack shelves. This proto-type used the 70-9B, 10 Watt, rf power amplifier. It also included a 2m FM receiver, ABOMY - Aruduino DTMF decoder / relay, video monitor and +13.8Vdc power supply.

70cm In-Band Repeater: This will be more complex to make work right and costly. Why? You need really great, ATV channel band-pass filters for both the receiver and transmitter to make it function properly without serious de-sense. These filters are not easy to come by, nor in-expensive. KH6HTV app. note AN-22b, "Inter-Digital Band-Pass Filters" discusses such filters and how you might build your own. Most builders of ATV repeaters are using ATV channel filters from DCI in Canada (***www.dcifilters.com***).

Note: DCI has been purchased recently by the Kavveri Telecom Products in Bangalore, India and communications with them now need to be addressed to ***mktg@kavveritelecoms.com*** For 70cm, ATV, DCI offers a 6 MHz filter in either 8 or 10 pole configuration. The price tag is not inexpensive. They are currently quoting $850 for the 8 pole filter and $1,050 for the 10 pole. Plus USA import duties. A 70cm TV repeater will need two filters.

Another alternative is Don Nelson, N0YE. In his home shop, he has built 70cm ATV filters using the design calculator discussed in AN-22b. Don's filters have more insertion loss than the DCI filters, but they are smaller and less expensive.

23cm to 70cm Repeater: A cross-band repeater is much simpler to build and less expensive. The exotic, $$$ BPFs are not required. Figure 1 is a photo of an example which I recently built. Fig. 2 is the fundamental block diagram showing the basic elements for a KISS repeater. Such a repeater could even be patched together in a few minutes in an emergency. Simply taking the HDMI output from a 23cm DVB-T receiver and patching it directly into the HDMI input of a 70cm transmitter. Attach appropriate antennas and bingo, you are on the air with a cross-band repeater.

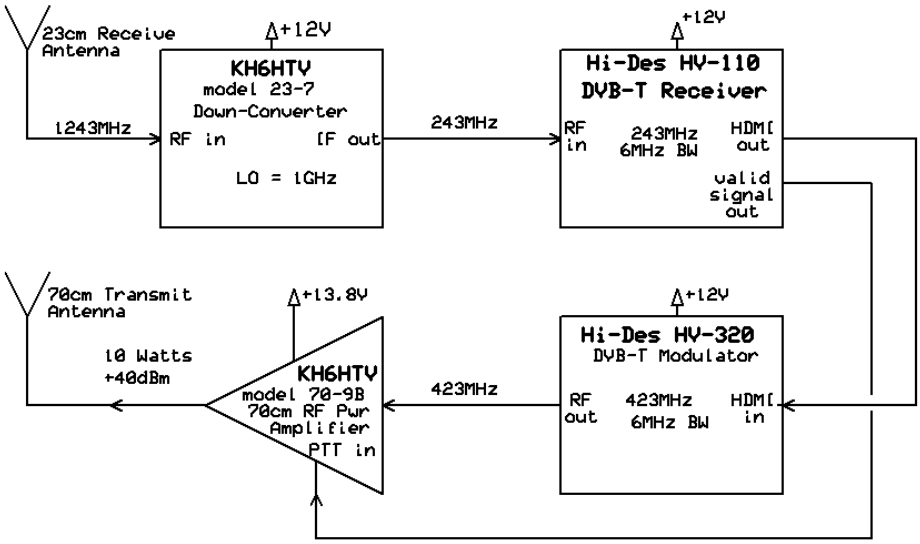

Fig. 2 Block Diagram of a basic, KISS, 23cm to 70cm DVB-T ATV Repeater

DVB-T Receiver and Modulator: I recommend using the specified Hi-Des units, the HV-110 receiver and HV-320 modulator. For an automatic controlled repeater, it is necessary to have a "Valid Signal" detector to key on/off the transmitter. A simple modification to the HV-110 receiver provides this logic signal for the PTT line. For details on this modification, see KH6HTV app. note, AN-23. For a very simple repeater thrown together on the fly, even this is not required. Simply have an on-site control operator manually turn on/off the transmitter.

23cm Receiver: The HV-110 receiver does not work up to the 23cm band. It works only up to the 33cm band. Thus a down-converter is required. The KH6HTV model 23-7 is used. It includes a low noise pre-amp, double balanced mixer and a frequency synthesized local oscillator. The LO is programmable. For this application, the LO was set to 1.0 GHz. For a 1243 MHz input, the IF output is thus 243 MHz.

RF Power Amplifier: The amplifier shown is the KH6HTV model 70-9B which produces a 10 Watt (+40dBm) DVB-T signal. Another suitable amp, if less power is required would be the model 70-7B with 3 Watts (+35dBm) output.

Performance? So what performance can be expected. The 23cm receive sensitivity is of the order of -95dBm (measured with "normal" DVB-T signal [1080p, 5.5Mbps, H.264, 6 MHZ BW, QPSK, 5/6 code, 1/16 guard]). RF output power of 10 Watts.

DC Power Required: The repeater is designed for +12Vdc operation (10-15V). At 13.8Vdc, the stand-by current draw is 2 Amps. When transmitting, it is about 9 Amps with the 70-9B amplifier.

Extra Features: As the basic repeater, Fig.2, it will operate independent of human direct control with the automatic Valid Signal detector driving the amplifier's PTT line. For FCC control purposes, a separate control capability is required. This could be accomplished by adding a 2 meter FM receiver. This receiver then drives a DTMF touch-tone decoder / relay driver to add remote control capability. This is shown in the expanded block diagram of Fig. 3. The actual prototype shown in Fig. 1 is an example. An additional nice feature is to have a local video monitor to look at the incoming signals.

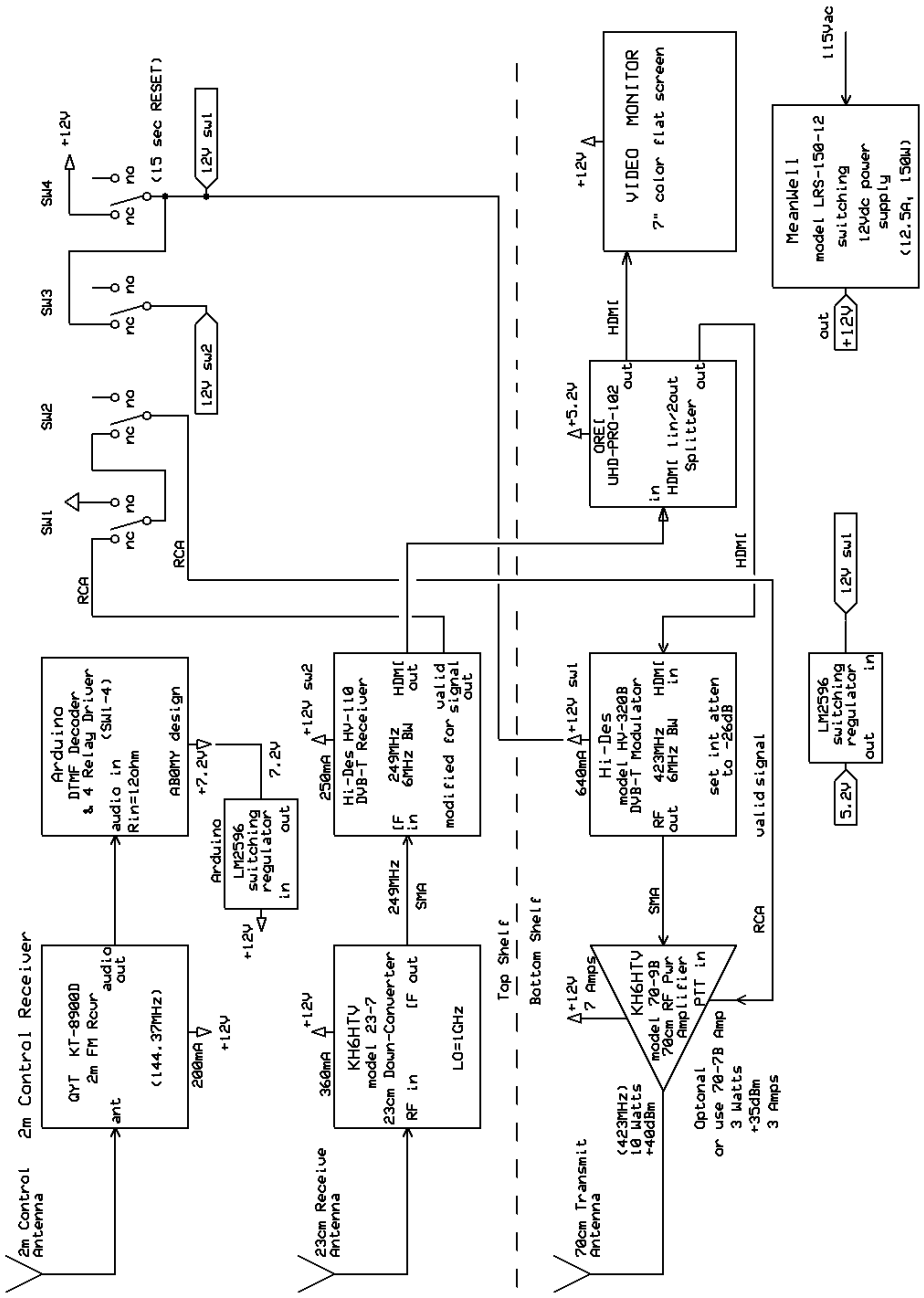

Fig. 3 Block Diagram of 23cm to 70cm Cross-Band, DVB-T repeater complete with 2 m control capabilities and video monitor.

Table 1 -- Major Components for 23-70 Repeater

Item	Mfgr.	Model #	Description
1	Hi-Des	HV-110	DVB-T receiver
2	Hi-Des	HV-320	DVB-T modulator
3	KH6HTV	70-9B	70cm, 10W, rf linear power amplifier
4	KH6HTV	23-7	23cm Down-Converter
5	Meanwell	LRS-150-12	12Vdc, 150 W Power Supply
6	AB0MY	TT-4relay	Arduino with custom touch-tone (DTMF) decoder & 4 relays + programming as desired
7	QYT	KT-8900D	2m FM mobile transceiver
8	Amazon	various	Video Monitor, 7" flat color screen, HDMI input, +12Vdc
9	OREI	HD-104	HDMI A/V splitter -- 1 in, 4 out, +5Vdc

Repeater Remote Control: To meet FCC requirements for an unattended repeater an alternate means of controlling or disabling the repeater is required. For the W0BTV, NCAR, ATV repeater this is done using touch-tones (DTMF) on a 2 meter control frequency. I suggest the same be used for this cross-band repeater. In years past, we have used a DTMF decoder / relay board from Intuitive Circuits. However, we no longer recommend them as we have had several failures. Their product dates back to the 1990s. We also had issues buying similar ones from Amazon. So recently Bill, AB0MY, has designed a new decoder using as it's basis an Arduino micro-controller. So we now recommend Bill's unit. It also has the advantage that Bill can custom program it to the user's specific control functions. For the prototype, the AB0MY DTMF decoder works as shown in Table II.

Table II --- Repeater Remote Control Functions

Function 3	Description	(*)	(#) normal state
1	Transmitter ON	ON	xmitter enabled
2	Transmitter Disabled	OFF	xmitter enabled
3	Color Bar Beacon	receiver OFF	receiver ON
4	Digital Reset	Reset (15 sec)	-- NA --

T-T Command Control Sequence = Password + Function # + either * or #
Password is CONFIDENTIAL (programmed as desired by AB0MY)
2 meter FM control frequency is CONFIDENTIAL (as desired, set on 2m receiver)

Normal State is with transmitter in enabled state awaiting a Valid Signal PTT

Function #1 forces the transmitter on even without an incoming signal

To transmit a Color Bar test pattern requires enabling function 3 plus function 1

If issues arise requiring the receiver and or modulator to have a system reset, then function #4 REST should be used. This removes the DC power from the receiver, modulator and HDMI splitter for 15 seconds and then reapplies power. It also resets the other relays back to the (#) normal state.
Relays 1 thru 3 are latching, Relay 4 is momentary (15 sec.)

Repeater ID: The FCC requires that all transmissions be identified, at least once every 10 minutes. For this repeater, we ID it continuously. As part of the A/V data stream there is also sent out a Metadata file with info about how the data is encoded. Included in this meta file is the transmitter's call sign. This is pre-programmed into the HV-320 modulator. The HV-110 receiver decodes the call sign of valid incoming DVB-T signals. The HV-110 receiver is set up to provide a permanent On Screen Display (OSD) of the call sign of the incoming signal along with the received signal strength in dBm and the signal to noise ratio in dB. This in then rebroadcast on the outgoing signal.

Additional BPFs: Depending upon your local RFI environment on the 23cm band, you may / or may not need to add an additional narrow-band, band-pass filter on the input to the receiver. Here in the Boulder / Denver metro area we are plagued with the presence of a very strong FAA radar operating in the middle of the 23cm band (1265-1270 MHz). The radar pulses overpower our DVB-T receivers and cause freeze-framing of the images. To solve this problem with our W0BTV DATV repeater we had to resort to a custom engineered and manufactured exotic band-pass / band-reject filter. This filter is discussed in detail in our application note, AN-53e. See pages 13-17. The application note also deals with N0YE's, 70cm BPFs.

Also depending upon local needs, you might also consider adding an ATV channel BPF on the output of the 70cm transmitter to clean up the out of channel skirts.

Antennas: This repeater is intended for use with three separate antennas. One for 23cm receive, one for 70cm transmit and one of 2 meter control. The selection of antennas is open to the user depending upon the coverage area desired, etc. There is a wide choice of antennas possible. Suggested reading is our application note, AN-67 "Comparison Tests of Various 70 & 23cm Antennas for ATV".

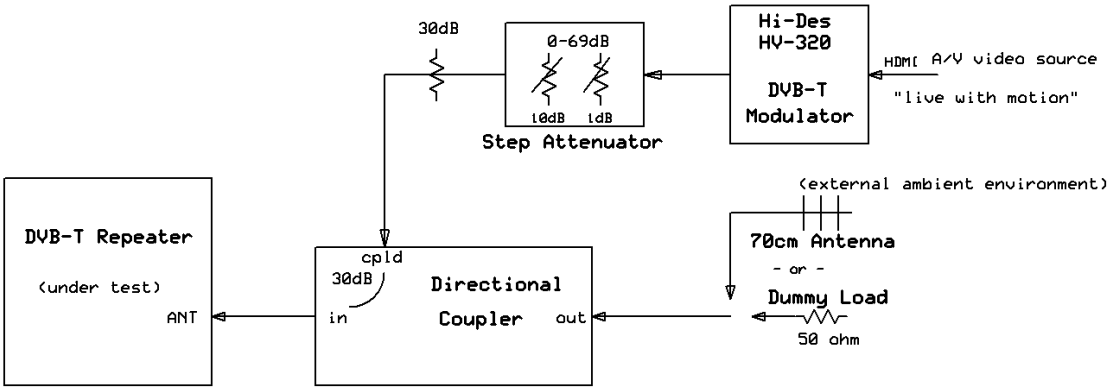

Fig. 4 Test Set for measuring the sensitivity of a DVB-T receiver

Final Test of Sensitivity: Fig. 4 above shows how to measure the sensitivity of a repeater's receiver both on the test bench and in a real world environment. A directional coupler is used to inject a known DVB-T test signal into the receive antenna port of the repeater.

Most DTV receivers tend to retain the last valid image decoded and display it on the screen. Thus if only a still image is transmitted as a test signal, it is difficult to know when the receiver is actually receiving properly -- or --- one is simply seeing a "Freeze-Frame". Thus it is important to use an A/V video source containing a lot of live motion and audio sounds. Playing back a DVD movie is ideal.

The first step is to set the modulator to a known RF output power level in dBm. Then knowing the amount of added attenuation in dB, it is straight forward to know the amount of rf power injected into the receiver under test. Pin = P(mod) - Attenuators - Directional Coupler.

Digital Receiver's Sensitivity is defined as the Digital Threshold which is the minimum rf signal level which results in a perfect P5 / Q5 picture & audio with no defects such as freeze framing. When using the Hi-Des HV-110 receiver a good visual indicator is also it's front panel red/green Valid Signal LED. It glows solid red with no signal. It glows solid green with P5/Q5 signal. It will flicker red - green with a weak signal just below digital threshold. Record the weakest signal level (in dBm) at which you get solid green. Also record the resultant signal to noise ratio S/N in dB.

Final Field Test: Using the above technique to measure receiver sensitivity the prototype cross-band repeater was tested. First on the test bench with a 50 ohm dummy load in place of an antenna, the 23cm sensitivity was found to be -96dBm (note: measured with "normal" DVB-T signal [1080p, 5.5Mbps, H.264, 6 MHZ BW, QPSK, 5/6 code, 1/16 guard]).

For the second test, in a real world environment, the dummy load was removed and replaced by a Diamond NR2000 mobile, 2m/70cm/23cm antenna mounted on an antenna mast outdoors. In this case, the repeater's receiver is going to be exposed to what ever other rf is flying around, other ham signals, FM repeaters, broad-band noise souces, etc. For the test at the qth of KH6HTV, the rf background degraded the sensitivity to about -65dBm. This was due to the strong Denver FAA radar pulses. Your actual sensitivity will vary depending upon your local RFI environment. This test showed that the basic 23-70 repeater is unusable in the Boulder area without an additional BPF on the receiver input.

For the third test, a KH6HTV Video model 23-NB BPF, narrow band-pass filter was added to the input of the receiver. This filter has a 15 MHz -3dB band-width. The filter used was tuned for a center frequency of 1240 MHz. Thus for ATV-Ch 1 on the 23cm band (i.e. 1243 MHz). this put the upper roll-off of the filter at about 1248 MHz. For the FAA radar at 1265-1270MHz this filter added > 30dB of attenuation. With a dummy load for an antenna, the receiver's basic sensitivity was degraded slightly by the filter's insertion loss to -94dBm. Then when the outside 23cm antenna was used, there was absolutely no degradation due to the FAA radar anymore. The basic repeater's over the air sensitivity remained at -94dBm. This was an extremely significant improvement of about 30dB over the performance without the BPF.