



## Application Note

**AN-38**

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# Shopping Lists for Amateur, DVB-T, Digital TV Equipment

**Jim Andrews, KH6HTV**

[www.kh6htv.com](http://www.kh6htv.com)

I have received numerous requests from radio amateurs interested in getting into amateur TV, all wanting to know (1) "How much will it cost me ?" and (2) "What all equipment do I need to purchase?". After doing many emails of correspondence, I have decided to put down in one reference able location, shopping lists for several possible station configurations. Hence this application note.

I am restricting this app. note to High Definition (1080P), Digital TV (DTV), using the European DTV broadcast standard, DVB-T [1]. The major emphasis will be on stations for the amateur 70cm band (420-450MHz). For hi-def (1080P), in the USA, we use typically the standard FCC authorized TV channel bandwidth of 6 MHz. Other countries in Europe and elsewhere are using 7 or 8 MHz BW for broadcast digital TV. We also use the standard 6 MHz, cable TV channels which land in the 70cm band [2]. These are: Ch57 (423), Ch58 (429), Ch 59 (435), Ch 60 (441) & Ch 61 (447MHz). Hams often simply refer to these as channels 1 thru 5. Note, that standard DTV convention is to designate the channel frequency as the center frequency of the channel. Of secondary interest, I will also cover items needed to expand a 70cm DTV station to also operate on the 23cm band (1240-1300MHz). [similar items can also be obtained for the 33cm band (902-928MHz)] I will also cover what is needed for a simple, portable DTV repeater.

At the bottom of this app. note, I list the many different sources to obtain the needed items. The prices listed are typical, retail list prices obtained from the internet. With careful shopping around and surfing online on the internet, the serious shopper can often find even lower prices.

### **TV CAMERA & Other VIDEO SOURCES:**

Fundamental to all amateur TV stations is the requirement to have one or more sources of Audio / Video (A/V) material. This can be a TV camera, TV camcorder, VCR, DVD or Blu-Ray disc player, or a computer. With this equipment, one can transmit "live" video, pre-recorded video and computer monitor screen images. The digital A/V output format used for amateur DTV is the consumer HDMI. Composite video (yellow RCA

connector) can also be used, but it is only standard definition with 480i max. resolution. When using composite video, a converter to HDMI will be required. These can be purchased on the internet for typically \$10-\$15. At a minimum, each ATV ham shack should include at least a TV camera. Great, suitable, Hi-Def camcorders with excellent zoom and optics can be purchased new from companies such as Canon, Sony, etc. in the very reasonable \$200 - \$300 price range.

| Item   | Description  | Mfgr.  | Model # | Price         | Source |
|--------|--|--------|---------|---------------|--------|
| CAMERA | Camcorder: Hi-Def (1080P), HDMI A/V output, plus USB, requires memory card | CANON  | HF-R800 | \$300 or less | 3      |
| memory | 32GB SD Memory Card  | misc   |         | \$12          | 4, 5   |
| Tripod | sturdy, preferably with fluid head, level                                  | Sunpak | 620-840 | \$57          | 6      |

### DTV RECEIVER:

The basic ATV ham shack will require as a minimum a DVB-T receiver. These are not available in the USA as a complete TV receiver with display screen which will also tune the amateur 70cm band (420-450MHz). One must buy a separate "set-top" box receiver with an HDMI output and connect it, via an HDMI cable, to any Hi-Def (1080P minimum), flat screen monitor of what ever size desired. For any portable operation where 115Vac power is not available, one will require a 12Vdc HDMI monitor. These are much more difficult to find and typically come in sizes from 7" to 22". The ATV amateur should always have at least 70cm receive capability. Adding higher bands, such as 33cm, 23cm, etc. requires additional equipment.

| Item            | Description   | Mfgr.                      | Model #                 | Price       | Source |
|-----------------|---|----------------------------|-------------------------|-------------|--------|
| DVB-T RCVR      | DVB-T. must receive 70cm band (420-450MHz) with at least 6MHz band-width HDMI & composite video outputs   | KH6HTV VIDEO               | 70-14                   | \$90        | 1      |
| -- opt DC       | adds +12Vdc operation, plus "Valid Signal" output for PTT   | KH6HTV VIDEO               | 70-14-DC                | +\$60       | 1      |
| Pre-Amplifier   | 70cm, 18dB gain, 0.5dB NF, +12Vdc (ok to power with surplus 12Vdc wall wart)  | Advanced Receiver Research | P432VDG                 | \$100       | 7      |
| Video Monitor   | 1080P min. resolution, flat screen, HDMI input, 115Vac -- size as desired   | many sources               |                         | \$125 on up | many   |
| Video Monitor   | for portable operation from +12Vdc 13" LED flat screen, 1080P, HDMI   | Super-Sonic                | SC-1311                 | \$100       | 8      |
| HDMI Cable      | to connect rcvr to monitor. length as needed  |                            |                         | \$5 +       | 11     |
| Antenna         | for base station use -- recommend X-50NA [4], 2m/70cm, omni-directional, 66" length, N connector, 12dBi (70cm)  | Diamond                    | X-50NA                  | \$95        | 9, 10  |
| Coax Cable      | 50Ω, - must use very low loss coax, N connectors - suggest LMR-400 or equivalent - length required depends upon installation price will vary depending upon length, etc | DX Engineering             | DXE-400MAX DN050 (50ft) | \$78        | 10     |
| coax adapter    | N(female) / BNC (male) - for antenna to pre-amp   |                            |                         | \$5         | 11     |
| BNC patch cable | to interconnect pre-amp to dtv rcvr. length as needed.  |                            |                         | \$8         | 11     |
| coax adapter    | BNC (female) to F (male) - for preamp to dtv rcvr   |                            |                         | \$4         | 11     |

**BASE STATION DTV TRANSMITTER:**

The typical DTV ham will start out with his own 70cm DTV base station in his home QTH ham shack. The following items are required. Note: this table includes it's own transmit antenna. If a single 70cm antenna is to be used for both DTV transmit and receive, then a coax switch will be necessary to switch the antenna from transmit to receive. This can either be a manual switch, or coax relay. Caution: never operate the linear amplifier into an open switch. It must always be terminated into a 50Ω antenna. Failure to do this will result in a blown-out final amplifier.

| Item                      | Description   | Mfgr.          | Model #                 | Price   | Source  |
|---------------------------|---|----------------|-------------------------|---------|---------|
| A/V Source                | see above table for TV Cameras, etc.<br>HDMI A/V output to modulator  |                |                         |         |         |
| DVB-T Modulator           | HDMI A/V input 50-950MHz & 1200-1350MHz   | Hi-Des         | HV-100EH or HV-102EH    | \$560   | 2       |
| RF Linear Power Amplifier | 10 Watts (DTV, avg) rf output, 50dB gain adj 10/3/1W, +13.8Vdc @ 10/3/2 Amps  | KH6HTV VIDEO   | 70-9B                   | \$450   | 1       |
| +13.8Vdc Power Supply     | +13.8Vdc, 20 Amps min. rating. Must support 10 Amps at 100% duty cycle<br>Do NOT buy Samlex -- poor reliability !   | several mfgs   |                         | \$125   | 9, 10   |
| Antenna                   | for base station use -- recommend X-50NA [4], 2m/70cm, omni-directional, 66" length, N connector, 12dBi (70cm)  | Diamond        | X-50NA                  | \$95    | 9, 10   |
| Coax Cable                | 50Ω, must use very low loss coax, N connectors - suggest LMR-400 or equivalent - length required depends upon installation<br>price will vary depending upon length, etc        | DX Engineering | DXE-400MAX DN050 (50ft) | \$78    | 10      |
| SMA jumper cable          | SMA / SMA, 50Ω, patch cable to connect modulator to linear amplifier, length as needed, 1 ft. min.  | various        |                         | \$8     | various |
| F attenuators             | type F connector (m/f) -- needed to set proper rf drive level from modulator to linear amplifier. available in 3, 6, 10, 12, 16 & 20dB values. suggest buying several. - cheap! | ATV Research   | FAM-XdB                 | \$1 ea. | 12      |
| Coax Adapter              | F (male) to SMA (female) -- for output from modulator   | various        |                         | \$5     | various |

**MOBILE STATION DTV TRANSMITTER:**

The mobile station is similar to the base station. All equipment works off of 12Vdc. The power source is the vehicle storage battery.

| Item                      | Description  | Mfgr.        | Model #              | Price   | Source  |
|---------------------------|--|--------------|----------------------|---------|---------|
| A/V Source                | see above table for TV Cameras, etc.<br>HDMI A/V output to modulator   |              |                      |         |         |
| DVB-T Modulator           | HDMI A/V input 50-950MHz & 1200-1350MHz  | Hi-Des       | HV-100EH or HV-102EH | \$560   | 2       |
| RF Linear Power Amplifier | 10 Watts (DTV, avg) rf output, 50dB gain adj 10/3/1W, +13.8Vdc @ 10/3/2 Amps   | KH6HTV VIDEO | 70-9B                | \$450   | 1       |
| SMA jumper cable          | SMA / SMA, 50Ω, patch cable to connect modulator to linear amplifier, length as needed, 1 ft. min.                           | various      |                      | \$8     | various |
| F attenuators             | type F connector (m/f) -- needed to set proper rf drive level from modulator to linear amplifier. available in 3, 6, 10, 12, | ATV Research | FAM-XdB              | \$1 ea. | 12      |

|                     |  |         |           |      |         |
|---------------------|--|---------|-----------|------|---------|
|                     | 16 & 20dB values. suggest buying several. - cheap!                           |         |           |      |         |
| Coax Adapter        | F (male) to SMA (female) -- for output from modulator                        | various |           | \$5  | various |
| Mobile Whip Antenna | recommend NR2000NA<br>7dBi (70cm) & 7dBi (23cm), N connector                 | Diamond | NR2000NA  | \$85 | 9, 10   |
| Mag. Mount          | magnetic mount for above NR2000NA, N, 13ft. low loss coax, N connector       | Diamond | DPK-4NM-N | \$55 | 9, 10   |
|                     | -- or -- for a fixed installation, pick a suitable mobile mount from Diamond |         |           |      |         |

### MOBILE STATION DTV RECEIVER:

The mobile station is similar to the base station receiver. However, all equipment must work off of 12Vdc. The power source is the vehicle storage battery.

| Item                | Description   | Mfgr.                      | Model #   | Price | Source |
|---------------------|---|----------------------------|-----------|-------|--------|
| DVB-T RCVR          | DVB-T. must receive 70cm band (420-450MHz) with at least 6MHz band-width HDMI & composite video outputs | KH6HTV VIDEO               | 70-14     | \$90  | 1      |
| -- opt DC           | adds +12Vdc operation, plus "Valid Signal" output for PTT   | KH6HTV VIDEO               | 70-14-DC  | +\$60 | 1      |
| Pre-Amplifier       | 70cm, 18dB gain, 0.5dB NF, +12Vdc   | Advanced Receiver Research | P432VDG   | \$100 | 7      |
| Video Monitor       | for portable operation from +12Vdc 13" LED flat screen, 1080P, HDMI                                     | Super-Sonic                | SC-1311   | \$100 | 8      |
| HDMI Cable          | to connect rcvr to monitor. length as needed  |                            |           | \$5 + | 11     |
| coax adapter        | N(female) / BNC (male) - for antenna to pre-amp   |                            |           | \$5   | 11     |
| BNC patch cable     | to interconnect pre-amp to dtv rcvr. length as needed.  |                            |           | \$8   | 11     |
| coax adapter        | BNC (female) to F (male) - for preamp to dtv rcvr   |                            |           | \$4   | 11     |
| Mobile Whip Antenna | recommend NR2000NA<br>7dBi (70cm) & 7dBi (23cm), N connector  | Diamond                    | NR2000NA  | \$85  | 9, 10  |
| Mag. Mount          | magnetic mount for above NR2000NA, N, 13ft. low loss coax, N connector                                  | Diamond                    | DPK-4NM-N | \$55  | 9, 10  |
|                     | -- or -- for a fixed installation, pick a suitable mount from Diamond                                   |                            |           |       |        |

### BACK-PACK, PORTABLE, DTV TRANSMITTER:

For many ARES operations, it is necessary to have "feet on the ground" to get in up close to the emergency situation. The June, 2015, QST article [4] gives a good description, including photos. The typical setup consists of an inexpensive camcorder on a tripod, 3 watt DVB-T transmitter (adjustable to lower power levels & lower current draw), rubber duck whip antenna on an antenna bracket mounted on the tripod, plus a 12Vdc, sealed battery for power. The battery and transmitter are transported in a back-pack. Low cost, sealed gell cell batteries can be used. For much longer operational life, very expensive Li-Ion batteries should also be considered.

| Item      | Description  | Mfgr. | Model # | Price         | Source |
|-----------|--|-------|---------|---------------|--------|
| TV Camera | Camcorder: Hi-Def (1080P), HDMI A/V output, plus USB, requires memory card | CANON | HF-R800 | \$300 or less | 3      |

|                           |   |                       |                      |         |                  |
|---------------------------|---|-----------------------|----------------------|---------|------------------|
| memory card               | 32GB SD Memory Card<br>suggest you purchase several   | misc                  |                      | \$12    | 4, 5             |
| Tripod                    | sturdy, preferably with fluid head, level   | Sunpak                | 620-840              | \$57    | 6                |
| spare batteries           | suggest buying extra batteries for camcorder  | Canon & other sources |                      | \$30+   | 6, 8, 14 various |
| battery charger           | charger for extra batteries   | Canon & others        |                      | \$50    | 6, 8, 14 various |
| sun shade                 | to shield LCD screen from direct sunlight   | various               |                      | \$12    | 8                |
| rain cover                | see AN-16 for details, [6]  |                       |                      | \$5     | home built       |
| antenna bracket           | see AN-15 for details [5]   |                       |                      | \$15    | home built       |
| DVB-T Modulator           | HDMI A/V input 50-950MHz & 1200-1350MHz   | Hi-Des                | HV-100EH or HV-102EH | \$560   | 2                |
| RF Linear Power Amplifier | 3 Watts (DTV, avg) rf output, 50dB gain adj 3/1/0.3W, +12Vdc @ 3/1/0.7 Amps   | KH6HTV VIDEO          | 70-7B                | \$340   | 1                |
| SMA jumper cable          | SMA / SMA, 50Ω, patch cable to connect modulator to linear amplifier, length as needed, 1 ft. min.  | various               |                      | \$8     | various          |
| F attenuators             | type F connector (m/f) -- needed to set proper rf drive level from modulator to linear amplifier. available in 3, 6, 10, 12, 16 & 20dB values. suggest buying several. - cheap! | ATV Research          | FAM-XdB              | \$1 ea. | 12               |
| Coax Adapter              | F (male) to SMA (female) -- for output from modulator   | various               |                      | \$5     | various          |
| Whip Antenna              | recommend RH951S, 2dBi (70cm), 14", BNC 2m/70cm/23cm  | Diamond               | RH951S               | \$45    | 9, 10            |
| Antenna Cable             | low loss, RG-58 size, BNC, 6 ft.  | various               |                      | \$20    | various          |
| Coax Adapter              | N (male) to BNC (female) -- for output from amplifier to antenna  | various               |                      | \$10    | various          |
| Battery                   | Sealed lead acid, Gell Cell -- 12Vdc, 7 Amp-Hour minimum size.<br>suggest you purchase several.   | Power-Sonic           | PS-1280F2            | \$32    | 13               |
| Battery Charger           | Automatic Gell Cell Charger, switch mode, for 4 to 8 Amp-Hr batteries, 115Vac   | Power-Sonic           | PSC-12800A-C         | \$31    | 13               |
| DVM                       | Digital Volt Meter -- to monitor state of battery.  | various               |                      | \$10    | various          |
| Back-Pack                 | Suitable to carry modulator, linear amplifier, battery, plus other accessories  | various               |                      | \$75    | various          |

### PORTABLE DTV REPEATER:

A simple, manually controlled, portable DTV repeater is relatively simple to assemble. For details, see AN-23A [7] It simply consists of using an HDMI cable to connect the output of a DTV receiver directly to the input of a DTV transmitter. The DTV receiver's Valid Signal LED indicator is used to provide a PTT control to the transmitter's PTT line.

| Item          | Description   | Mfgr.                      | Model #  | Price | Source |
|---------------|---|----------------------------|----------|-------|--------|
| DVB-T RCVR    | DVB-T. must receive 70cm band (420-450MHz) with at least 6MHz band-width HDMI & composite video outputs | KH6HTV VIDEO               | 70-14    | \$90  | 1      |
| -- opt DC     | adds +12Vdc operation, plus "Valid Signal" output for PTT   | KH6HTV VIDEO               | 70-14-DC | +\$60 | 1      |
| Pre-Amplifier | 70cm, 18dB gain, 0.5dB NF, +12Vdc   | Advanced Receiver Research | P432VDG  | \$100 | 7      |

|                           |   |              |                      |            |       |
|---------------------------|---|--------------|----------------------|------------|-------|
| HDMI splitter             | Active HDMI signal splitter. 1 Input & 2 Outputs -- use 1 output to monitor, use other output to transmitter  | various      |                      | \$25       | 8     |
| Video Monitor             | for portable operation from +12Vdc 13" LED flat screen, 1080P, HDMI   | Super-Sonic  | SC-1311              | \$100      | 8     |
| HDMI Cable                | to connect rcvr to monitor. length as needed  |              | need 2 cables        | \$5 +      | 8, 11 |
| DVB-T Modulator           | HDMI A/V input 50-950MHz & 1200-1350MHz   | Hi-Des       | HV-100EH or HV-102EH | \$560      | 2     |
| RF Linear Power Amplifier | 6 Watts (DTV, avg) rf output, 50dB gain adj 6/2/0.6W, +12Vdc @ 5/1.3/0.8 Amps<br>NOTE: could also use either 70-7B or 70-9B amplifier                 | KH6HTV VIDEO | 70-12C               | \$380      | 1     |
| Band-Pass Filters         | 70cm, 6MHz BW, Inter-digital, Band-Pass filters. 2 required. 1 for receiver, 1 for transmitter  | KH6HTV VIDEO | 70-BPF-5P-6M-XXX     | \$325 ea.  | 1     |
| misc.                     | also need an assortment of coax adapters, coax patch cables, etc.   |              |                      |            |       |
| Container                 | a rugged container / carrying case is required with all components securely attached. Suitable cases are available from the music industry, etc.      |              |                      | \$300 est. |       |
| ANTENNA                   | typical configuration uses (2) wide spaced yaggi antennas. Other antennas can also be used, but must take care to minimize coupling between antennas. |              |                      |            |       |
| +13.8Vdc Power Supply     | +13.8Vdc, 20 Amps min. rating. Must support 10 Amps at 100% duty cycle<br>Do NOT buy Samlex -- poor reliability !                                     | several mfgs |                      | \$125      | 9, 10 |
| Batteries                 | large automobile storage battery -- or several gell cells   |              |                      |            |       |
|                           |   |              |                      |            |       |
|                           |   |              |                      |            |       |

### HIGH GAIN YAGGI ANTENNA:

For any of the transmit or receive situations, be they portable, mobile, repeater or base station, there may be situations where a high gain, directional antenna is required. Not just any antenna is suitable for TV service. Any antenna used for TV must be extremely broadband, capable of covering the entire amateur radio band. For details on recommended antennas see AN-4 [3].

| Item        | Description  | Mfgr.                        | Model #                       | Price          | Source |
|-------------|--|------------------------------|-------------------------------|----------------|--------|
| Antenna     | 6 element Yaggi, 70cm, 13dBi, N connector, end mount   | M-Squared                    | 440-6SS                       | \$80           | 9      |
| Ant. Tripod | classical roof mount antenna tripod<br>several choices available at Wal-Mart-online only (not in stores)   |                              |                               | \$30           | 5      |
| Ant. Masts  | as desired, stackable 5ft. sections - or - 15 ft. telescoping  | various<br>Channel<br>Master | ---<br>CM-1820                | \$10ea<br>\$71 | 5      |
| Coax Cable  | 50Ω, must use very low loss coax, N connectors - suggest LMR-400 or equivalent - length required depends upon installation<br>price will vary depending upon length, etc | DX<br>Engineering            | DXE-400MAX<br>DN050<br>(50ft) | \$78           | 10     |

### 33cm BAND OPTION:

The next higher amateur radio band is the 33cm band at 902-928 MHz. Wideband TV is also allowed in this band and all higher microwave bands. This band suffers from a lot of RFI due to unlicensed devices. All of the basic 70cm DTV equipment is still required. The Hi-Des model HV-100EH or HV-102EH will work on this band also. The key extra items needed include an receiver, pre-amp, RF linear power amplifier, and antenna(s).

| Item                      | Description   | Mfgr.           | Model #                       | Price                    | Source |
|---------------------------|---|-----------------|-------------------------------|--------------------------|--------|
| Receiver                  | DVB-T, must tune beyond 928MHz<br>HV-110 covers 70cm & 33cm<br>HV-120A covers 70cm, 33cm, 23cm & 13cm | Hi-Des          | HV-110<br>-- or --<br>HV-120A | \$169<br>--or--<br>\$209 | 2      |
| Pre-Amp                   | need >15dB gain, < 1dB NF   | KH6HTV<br>VIDEO | 23-4LNA<br>opt - 33cm         | \$100                    | 1      |
| RF Linear Power Amplifier | 2/0.6/0.2 Watts RF,<br>12Vdc @ 2.3/0.9/0.6 Amps<br>6/2/0.6 Watts RF<br>12Vdc @ 10/3/2 Amps            | KH6HTV<br>VIDEO | 33-1A<br>--or --<br>33-3B     | \$370<br>--or--<br>\$450 | 1      |
| Antenna(s)                | Directive Systems perhaps, untested by KH6HTV   |                 |                               |                          | 15     |

### 23cm BAND OPTION:

The second most popular amateur band for ATV is the 23cm band (1240 - 1300 MHz), which supports up to ten, 6 MHz bandwidth, TV channels. It is relative free from RFI except for some FAA radars. All of the basic 70cm DTV equipment is still required. The Hi-Des model HV-100EH or HV-102EH will work on this band also. The key extra items needed include an receiver, pre-amp, RF linear power amplifier, and antenna(s).

| Item                      | Description   | Mfgr.             | Model #                      | Price                | Source |
|---------------------------|---|-------------------|------------------------------|----------------------|--------|
| Receiver                  | DVB-T, must tune beyond 1300MHz<br>HV-120A covers 70cm, 33cm, 23cm & 13cm                                   | Hi-Des            | HV-120A                      | \$209                | 2      |
| Pre-Amp                   | need >15dB gain, < 1dB NF   | KH6HTV<br>VIDEO   | 23-4LNA                      | \$100                | 1      |
| RF Linear Power Amplifier | 3 W / 1 W / 300mW<br>12Vdc @ 4 / 2 / 1.2 Amps   | KH6HTV<br>VIDEO   | 23-11A                       | \$450                | 1      |
| Antenna - Base            | base station, omni-directional, 7dBi<br>2m/ 70cm / 23cm,<br>note: do not use on 70cm, except for 440-450MHz | Diamond           | X-6000A                      | \$                   | 9, 10  |
| Antenna Mobile            | 2m/70cm/23cm, 39", N connector<br>good for both 70cm & 23cm ATV   | Diamond           | NR2000NA                     | \$                   | 9, 10  |
| Mag. Mount                | magnetic mount for above NR2000NA,<br>N,<br>13ft. low loss coax, N connector                                | Diamond           | DPK-4NM-N                    | \$55                 | 9, 10  |
| Antenna-Portable          | rubber duck whip, 6m/2m/70cm/23cm,<br>20", SMA, 4dBi across band,<br>2m/70cm/23cm, 14", BNC, 1dBi to 4dBi,  | Diamond           | SRH999<br>-- or --<br>RH951S | \$<br>-- or --<br>\$ | 9, 10  |
| Antenna - Yaggi           | loop yaggi, 14 elements, 17-18dB across band, 3ft. boom, rear mount, N connector                            | Directive Systems | DSE2414LYRM                  | \$80                 | 15     |

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2. "70cm & Microwave Amateur TV Frequencies", Jim Andrews, KH6HTV Video application note, AN-10a, Oct, 2014.
3. "Antennas for Ham TV" Jim Andrews, KH6HTV Video application note, AN-4, Sept. 2011
4. "DVB-T: A Solutions for ARES Television Operations", Jim Andrews, June, 2015, ARRL magazine - QST, pp. 42-44.
5. "Simple Camera Tripod Antenna Bracket", Jim Andrews, KH6HTV Video application note, AN-15, Nov. 2013
6. "TV Camera Rain Cover", Jim Andrews, KH6HTV Video application note, AN-16, Nov. 2013
7. "DVB-T Television Repeater", Jim Andrews, KH6HTV Video application note, AN-23A, March, 2017

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2. Hi-Des Technology, [www.hides.com.tw](http://www.hides.com.tw), Taiwan
3. CANON, [www.usa.canon.com](http://www.usa.canon.com) note: often times, you can find better prices at stores such as Best Buy, Wal-Mart, etc.
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10. DX Engineering, [www.dxengineering.com](http://www.dxengineering.com) , Tallmadge, Ohio
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15. Directive Systems, [www.directiveystems.com](http://www.directiveystems.com) , Virginia