Application Note
AN-77

web = www.kh6htv.com email = kh6htv@arrl.net

Amateur Analog FM Television

Jim Andrews, KH6HTV

Today in 2026, a lot of the world's electronic communications are now done with some form or another of digital modulation. Yet there is still residual nostalgia for some of the old, original, analog modulation schemes. They are analog, NTSC, amplitude and frequency modulation (AM-TV & FM-TV) of television images. AN-75 dealt with AM-TV [2]. The purpose of this application note is to discuss FM-TV and what equipment is still available for amateur radio experimenters wanting to still keep this mode alive. Ref. [1] covers both AM, FM and digital TV.

TV HISTORY: The transmission of "live" video images via the radio air waves is now celebrating it's 100th anniversay. Television is an old RF communications technology dating back to the 1920s. Here is a brief early time line of those events.

- 1925 – QST reports on TV experiments using mechanical scanning
- 1926 – John Blair in Scotland, demos 1st working TV using mechanical scanning
- 1927 – Philo Farnsworth, 1st patent for all electronic scanned TV system
- 1929 – 1st TV broadcast, BBC, London
- 1933 -- Edwin Armstrong invents Frequency Modulation (FM)
- 1939 – NBS 1st live USA TV broadcast, New York City
- 1940 – 1st ham TV 2 way QSO,W2USA & W2DKJ in New York City, 56 & 112MHz
- 1940 - 1st use of FM-TV for microwave transmission of TV
- 1941 - FCC issues NTSC standard for AM-TV
- 1953 – Color added to TV, compatible with B&W
- 1972 -- 1st domestic satellite to carry TV - Canada's Anik-1
- 1974 -- 1st ATV repeater, WR4AAG, Metrovision ATV club, Alexandria, VA

- 1980-1986 -- TVRO / C-band Satellite Era, analog TV using wide-band FM-TV

The first recorded use of FM for transmitting TV was in 1940 when Philco engineers installed a microwave link between New York City and Philidephia. They become common place after WWII for long distance distribution of network TV. By 1951, the New York to San Francsico link was completed.

ATV HISTORY: Amateur TeleVision, (ATV) started to become popular among amateur radio experimenters in the 1960s and 70s using amplitude modulation (AM-TV). Some of the earliest ATV transmitters were modified, surplus, old taxi cab, UHF, FM voice transmitters. They were from companies such as Motorola, GE, RCA, etc. These were crystal controlled with only one 1 or 2 frequencies. Typically hams would tune them down to the 70cm ham band and do AM grid modulation with video of the final RF amplifier tube. Due to the narrow bandwidth of these transmitters, they were only capable of black & white video. The earliest ATV was done on the lowest band allowed by the FCC which was the 70 cm band. By the 1970s, 70cm, AM-TV transmitters using transistors started to appear.

By the 1970s, hams started using the higher microwave bands, starting with the 23cm. Due to wider available spectrum on these bands, hams also started experimenting with FM modulation for higher quality TV.

In 1978, low cost Gunnplexers became available for the 3 cm, 10 GHz band from Microwave Associates. They were extremely easy to FM modulate. So naturally hams began using them for both FM-voice and also FM-TV. They were the ultimate in simplicity for working that microwave band. They were a great encouragement for hams to experiment with the new, strange, ultra-short wave-length, X-band.

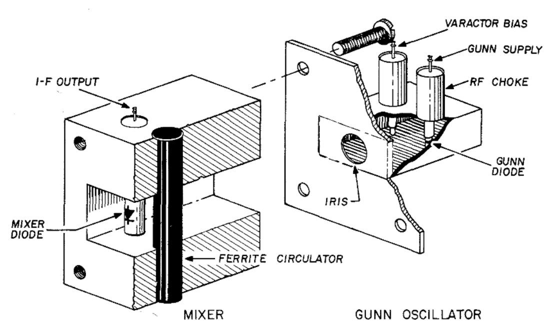


Figure 1-5.
Exploded drawing of the Gunnplexer cavity, ferrite circulator, and mixer diode (drawing courtesy *ham radio* magazine).

Fig. 1 10 GHz Gunnplexer

By the 1980s when satellite TV broadcasting became popular, hams started using surplus TVRO set-top receivers for 23 cm FM-TV. These set-top receivers were on L-band (1-2 GHz) which was the IF frequency down-converted from the C-band antenna front ends. These early analog TV satellites used extremely wide-band FM with deviations ranging from 12 to 18 MHz. They thus consumed a very large band-width of about 35 MHz. In contrast, terrestial, microwave TV links used lower deviations from 4 to 6 MHz with 4 MHz being the most common. Hams soon adopted the lower deviation standard of 4 MHz.

My research of early ATV publications was able to go back as far as 1988, when the **ATV Quarterly** first came out. It then was published by Henry Ruh, KB9FO, and Bill Brown, WB8ELK. The early magazines were chuck full of info running easily to 60 pages or more in length.

In the January 1989, vol. 2-1, issue of ATV Quarterly, I found the first ad for FM-TV. In it Don Miller's, W9NTP, company, Wyman Research, was offering FM-TV transmitters and receivers for the 23cm band. They were not inexpensive considering they were in 1989 dollars. $500 for each. Thus a cool kilo-buck then. Soon there after several others also offered FM-TV gear. See Figs. 2-5.

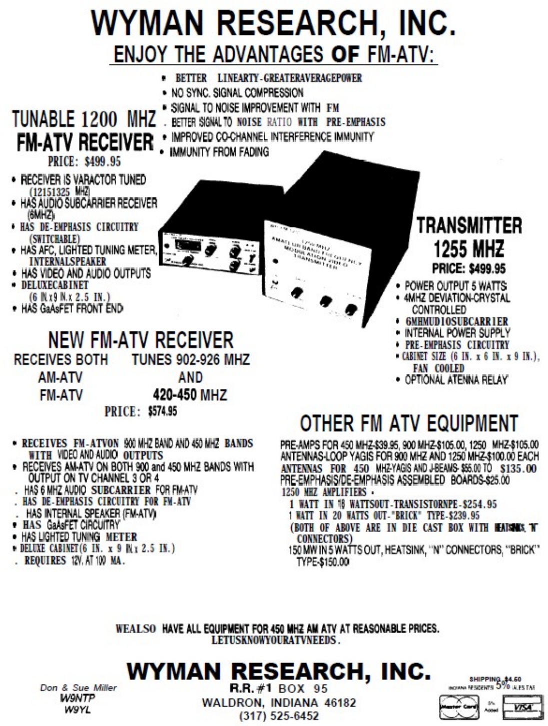
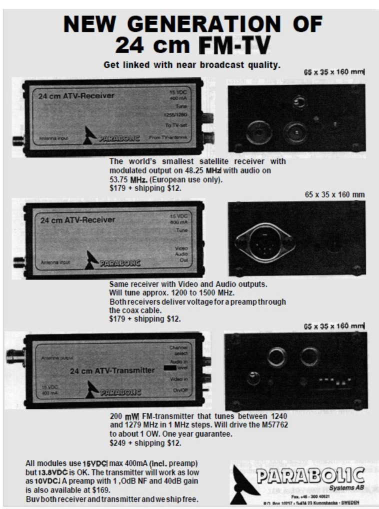
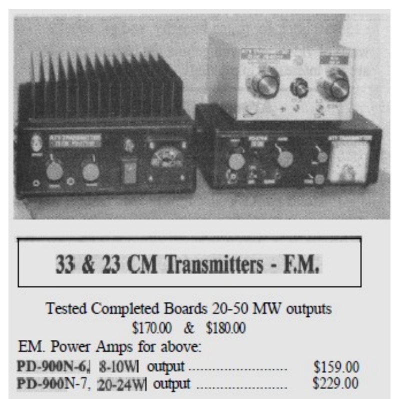


Fig. 2 Advertisement from 1989 for an early days amateur FM-TV gear for 23 cm



Parabolic - 1993

TD Systems - 1992



Pauldon - 1996

Fig. 3 Other manufacturers advertisements appearing in ATV Quarterly in the 90s

Also in the mid-90s, 2.4 GHz items appeared for the consumer market which appealed to ATV hams. They were called Video Senders and were marketed by Radio Shack and others. The most popular one was called the WaveCom Jr. They were a low powered (10mW) FM-TV transmitter and companion receiver intended for sending TV signals from one room to another within a house. They included a built-in patch antenna. ATV hams soon grabbed these low cost boxes and promptly modified them. Digging into them and removing the hard wired patch antenna and bringing the transmitter signal out via an SMA connector. Then adding an "After-Burner" RF power amplifier and outside antenna. Bingo, long distance FM-TV ATV DX.

Fig. 4 Wave-Com Jr. - 1996

By 1993, what I considered to be the ultimate, Rolls Royce of amateur FM-TV gear appeared on the market from HF Technology. I personally owned their gear and can vouch for it. They offered versions for the 33 cm, 23 cm and 13 cm band. They offered separate boxes as an FM-TV transmitter, down-converter and a 70 MHz IF amplifier / FM-TV demodulator.

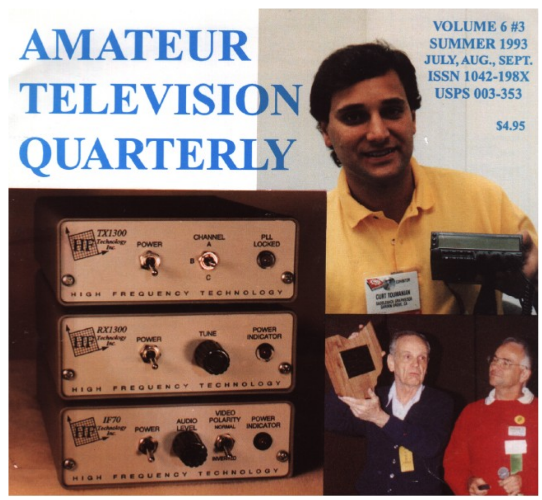


Fig. 5 HF Technology - 1993

TV BASICS: The basic concept of capturing a "live" video image consists of grabbing a sequence of still images at a fast enough rate that the human eye perceives them to be "live". In the motion picture industry, they found that a frame rate of 24 fps (frames per second) was sufficient. For TV, a frame rate of 30 fps (25 fps in Europe) is used. The historical reason for 30 fps rather than 24 was the presence of 60 Hz "hum" in the early day vacuum tube circuits. Using 1/2 * 60 Hz minimized the hum interference in video images. 50 Hz AC is used in Europe and most of the rest of the world, hence the 25 fps for their TV systems.

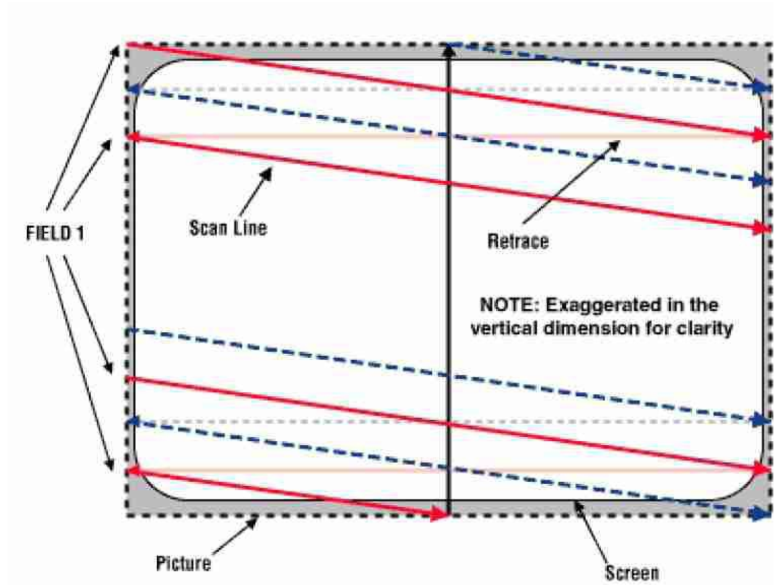


Fig. 6 Scanning on a CRT to display a TV image.

Until fairly recently, all of our TV receivers used a cathode ray tube (CRT) as the display device. A CRT presents a single spot (or pixel) on it's screen at any one time. The persistence in the phosphor made that spot glow for some time after it was illuminated by the electron beam. Thus, to present a complete image the electron beam needed to be swept (or scanned) sequentially across the CRT phosphor screen, from left to right and from top to bottom. To maintain synchronization between the initial image scanning camera and the display CRT a set of horizontal and vertical synchronizing pulses were required to maintain the proper timing.

During the early development of TV in the 1930s, many experiments were run, using the available technology of the time, and a set of TV standards were developed for scan rate, lines, etc. This was formulated by 1941, by the TV R&D people and the FCC into what is called the NTSC (National Television System Committee) standard. It resulted in the standard composite video signal with 525 horizontal scan lines at a 30 Hz frame rate. A CRT display would first sweep from left to right, then rapidly reset back to the left side of the screen and index down a line. See Fig. 6. When the scan finally reached the bottom of the screen, it would then be reset vertically to the top of the screen and a new frame would commence. These horizontal scan lines were interlaced with only 480 of them actually being visible. Hence the term 480 i. The remainder were masked during the vertical retrace time interval.

The base-band, composite video signal is standardized as a 1 Vptp signal into 75 Ohms. See Fig. 7. The various levels were measured in IRE (Institute of Radio Engineers) units, where 140 IRE = 1 Volt. The active video information occupied 100 IRE units and it could assume any value depending upon the gray level of the pixels. The horizontal and vertical sync pulses occupied 40 IRE units. The highest level was white. The lowest was the tip of the sync pulses. The vertical sync occurs at 29.97 Hz. The horizontal sync at 15.748 Hz. There are 525 lines per frame with 262.5 lines per field.

Two interlaced fields make up a single frame. Thus for 480 i video we have 640 x 480 pixels.

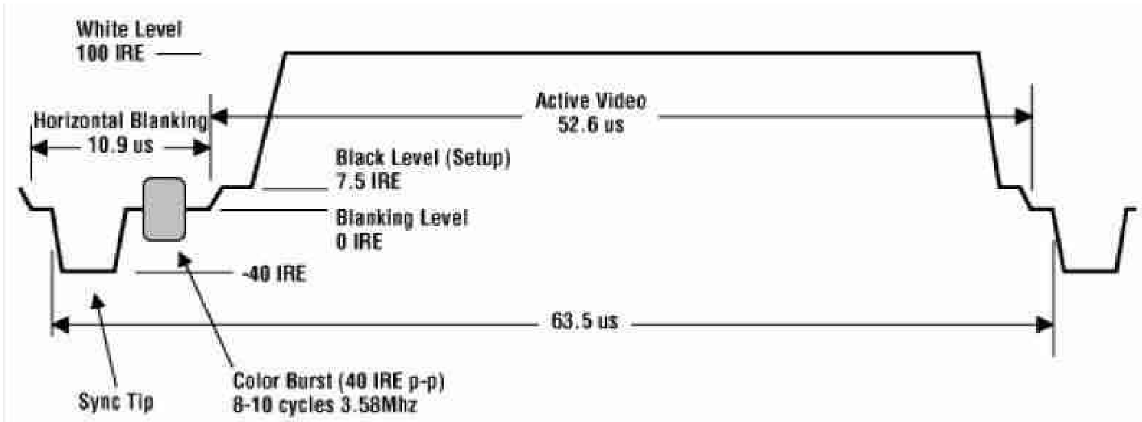


Fig. 7 Composite, base-band, Video Signal. 1 Volt p-t-p into 75 Ohms. 140 IRE units = 1 Volt. One horizontal line shown.

In 1953, NTSC added color to the basic TV signal. The color system adopted was designed to be backwardly compatible with the original black & white TV. This was done by adding a color sub-carrier (CSC) of 3.58 MHz with independent sidebands carrying the color information. The color burst shown in Fig. 7 was used to synchronize the 3.58 MHz color local oscillator in the receiver. Fig 8 shows a composite video signal carrying color information for a color bar test pattern.

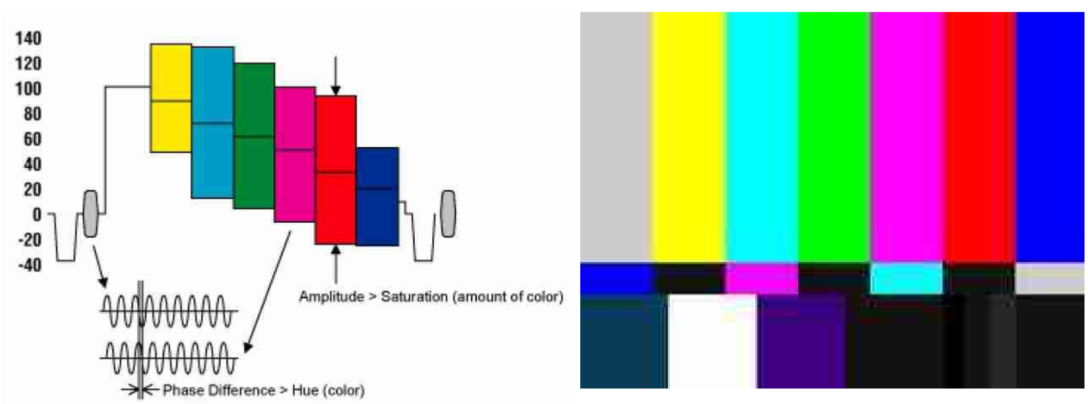


Fig. 8 Composite video signal with color bars & the resultant image on a video monitor.

Theoretical Discussion of AM & FM Modulation:

For a good discussion of various modulation techniques, including AM & FM, the reader is also referred to the ARRL's Handbooks [3] plus many sources on the internet.

AM: In amplitude modulation (AM), the frequency remains constant while the amplitude of the carrier varies with the amplitude of the modulating signal. The standard math formula for this process is given by:

$$s_{am}(t) = A_c [1 + m \cos (2 \pi f_m t)] \cos (2 \pi f_c t)$$

where A_c is the amplitude of the unmodulated carrier of frequency f_c f_m is the frequency of the modulating signal. m is the modulation index $m = A_m / A_c$ where A_m is the amplitude of the modulation signal.

FM: In frequency modulation (FM), the carrier frequency shifts in proportion to the modulating signal. Because this creates a nonlinear process, it generates an infinite number of side-bands. Bessel functions of the first kind provide the exact mathematical coefficients needed to calculate the amplitude and power of the carrier and these side-bands

MATH for FM Modulation:
For a single-tone modulating signal, the time-domain equation of an FM wave is:

$$s_{fm}(t) = A_c \cos\{ 2 \pi f_c t + \beta \sin (2 \pi f_m t) \}$$

This can the be expanded into the frequency domain using Bessel functions as:

$$S_{fm} = A_c \Sigma^{\infty}_{n=-\infty} J_n (\beta) \cos \{ 2 \pi (f_c + n f_m) t \}$$

Where: A_c is the unmodulated carrier amplitude; f_c is the carrier frequency; f_m is the modulating frequency; n is the side-band order; $J_n (\beta)$ is the Bessel function of the first kind of order n ; β is the modulation index, which is defined as $\beta = \Delta f / f_m$ where Δf is the peak frequency deviation. See Fig. 9 for a plot of Bessel functions.

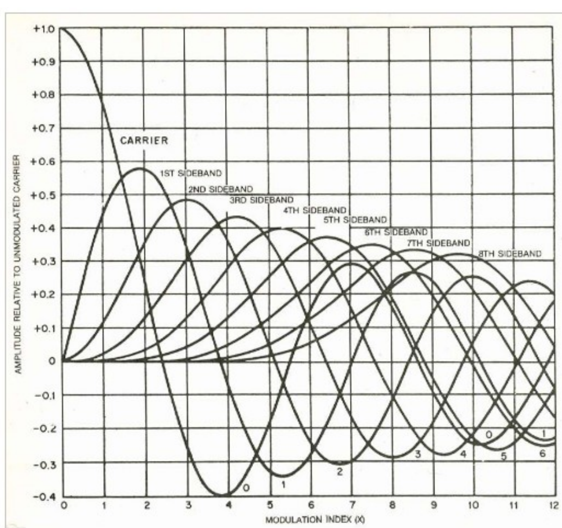
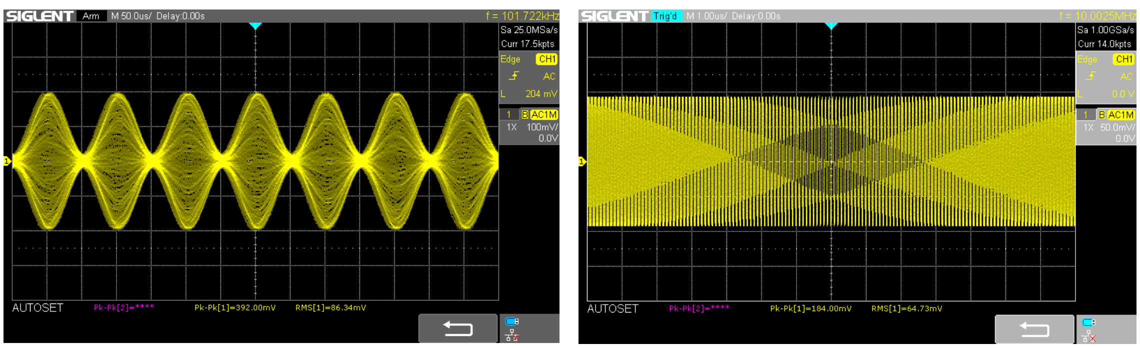


Fig. 9 Bessel functions showing the various side-bands for FM (from ARRL [3])

Thus the FM spectrum consists of a carrier frequency, f_c , and symmetric side-band frequencies, like double-side-band AM), but now with an infinite number of decaying side-bands, unlike AM. The side-bands are spaced apart by the modulating frequency, f_m . The side-band amplitudes are determined by the Bessel coefficient $J_n (\beta)$

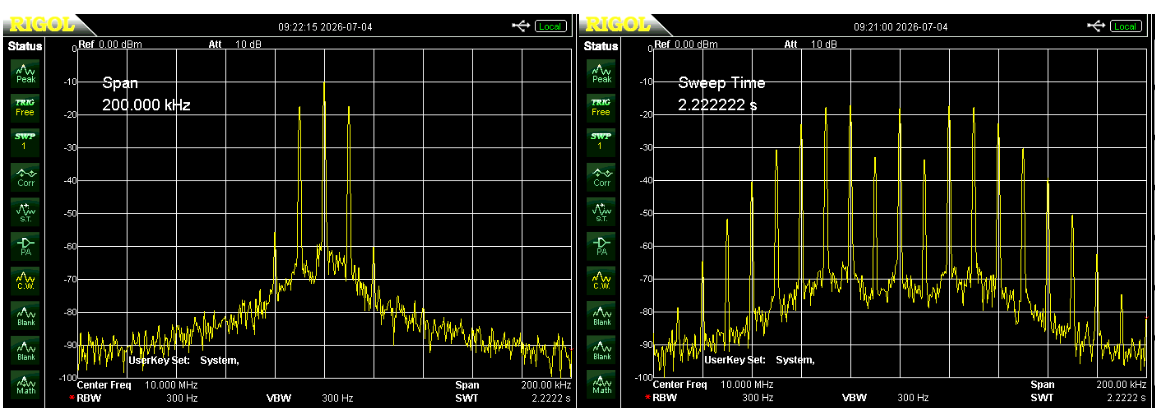
The band-width of FM is in theory extends to infinity. In practice, due to the decay of the Bessel functions, it is finite. Carson's Rule gives a good estimate of the practical band-width. It is: $BW \approx 2 (\Delta f + f_m)$

Examples of AM & FM: To help make the distinction between AM & FM clearly, I have run some practical experiments to visually demonstrate the differences for the reader. I used an HP-8640B signal generator to generate known AM and FM signals. I then observed the signals in the time domain on a Siglent SDS-1202 oscilloscope. I observed the signals in the frequency domain on a Rigol DSA-815 spectrum analyzer. The carrier frequency was set to 10 MHz. The modulating signal frequency was set to 10 kHz. For AM, the modulation level was set to 90%. For FM, the frequency deviation was set to 25 kHz. The results are shown below in Figs. 10 & 11.



AM FM

Fig. 10 Time domain display of a 10 MHz carrier modulated at 10 kHz by AM (left) and FM (right). 50 µs/div, span of 500 µs



AM FM

Fig. 11 Frequency domain display of a 10 MHz carrier modulated at 10 kHz by AM (left) and FM (right). 10dB/div vertical and 20 kHz/div horizontal, total span is 200 kHz.

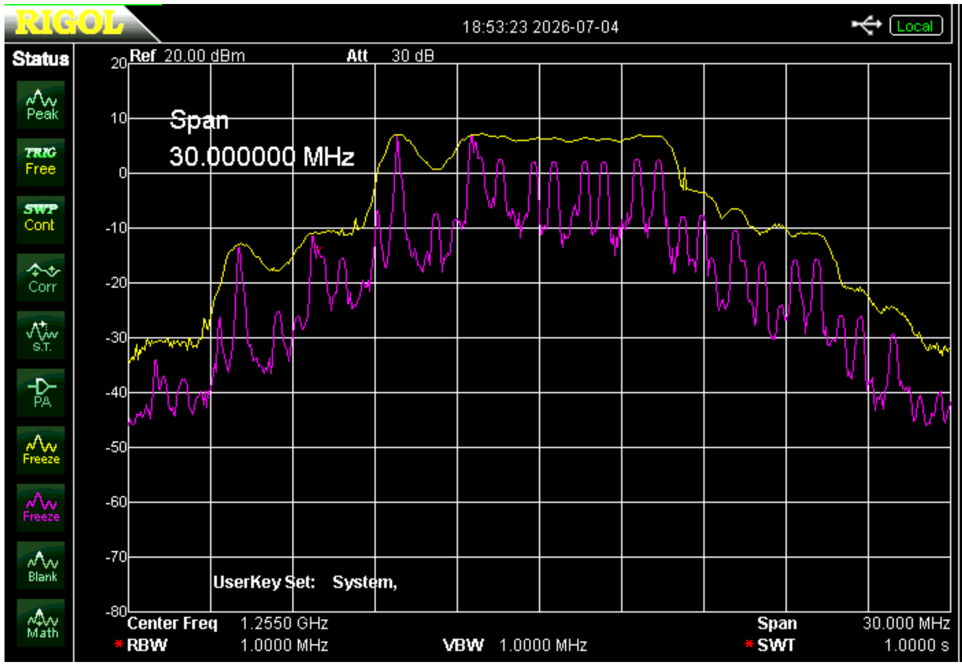
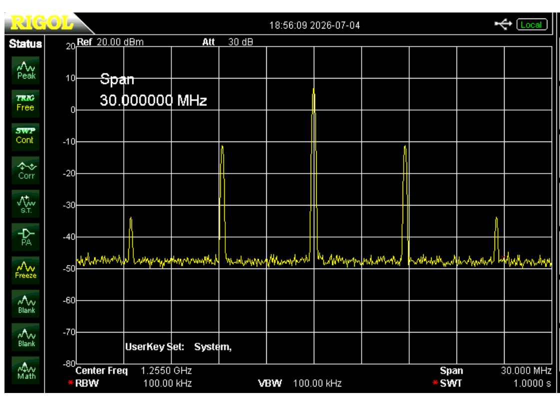


Fig. 12 RF Spectrum of a typical FM-TV Transmitter -- video only, no sound sub-carrier. 10 dB/div vert. & 3 MHz/div. horiz., 30 MHz span Yellow trace = 1 MHz RBW, magenta trace = 100 kHz RBW Video was NTSC color bar test pattern.

FM-TV SPECTRUM: Figs. 12-14 show measured rf spectrums for a typical FM-TV transmitter. The transmitter was set up with a flat frequency response and no pre-emphasis and positive polarity. The deviation was set to 4 MHz. The transmitter included a 5.8 MHz sound sub-carrier (SSC). The video test signal was an NTSC standard color bar test pattern and also "live" video (Fig. 14).



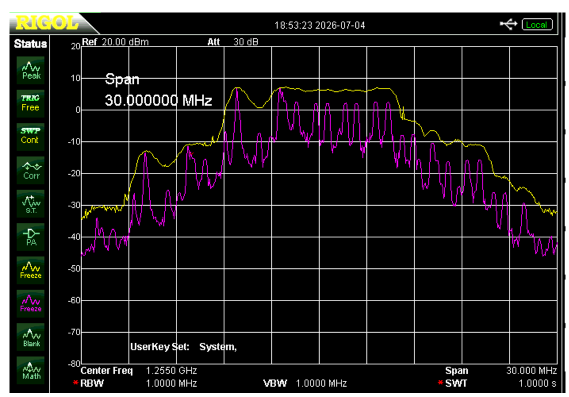


Fig. 13 RF Spectrum of a typical FM-TV transmitter with Sound Sub-Carrier. Left photo is with no video input. Right photo is with standard color bar video input. 10 dB/div & 3 MHz/div.

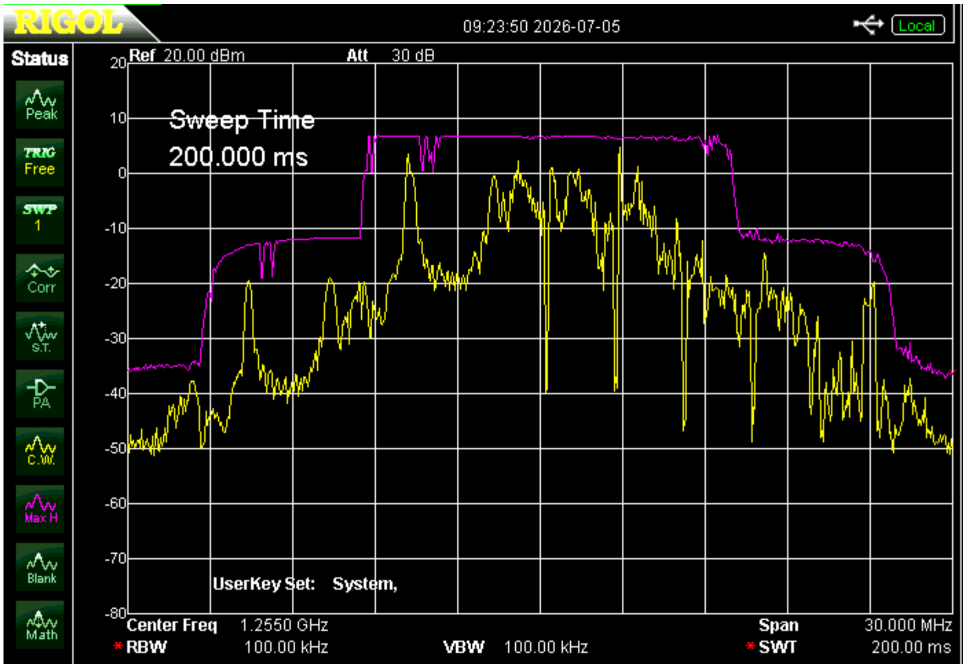


Fig. 14 RF Spectrum of a typical FM-TV Transmitter with SSC. This time with "live" video with lots of motion painting the spectrum. 100 kHz RBW. Yellow trace is single sweep. Magenta is peak hold for period of several minutes. 10 dB/div vert. & 3 MHz/div. horiz., 30 MHz span

Amateur Bands Suitable for FM-TV: As one can see from the above spectrum plots, FM-TV is inherently very broad-band and consumes a lot of spectrum. If we look at the amateur bands, the FCC allows us to do "fast scan" TV on, it should be obvious that we should NOT use FM-TV on our 70 cm band. Our 70 cm band from 420 to 450 MHz is 30 MHz wide. Far larger than all of our HF bands combined. But look at Figs. 12-14 with a span of 30 MHz. Note how much of the band is consumed by one, single FM-TV transmission. The conclusion should be obvious. We must restrict our use of the 70 cm band for ATV to TV channels of 6 MHz width or less. Our other higher frequency microwave bands above 1 GHz offer more spectrum space. The 23 cm band has 60 MHz. The 13 cm band has 70 MHz. The 9 cm band has 150 MHz. The 5 cm band has 275 MHz. The 3 cm band has a huge 500 MHz for us to play with. Thus, we must limit our use of FM-TV to the 23 cm band or higher.

ADVANTAGES of FM over AM: As hams, we all are very familiar with the advantages of FM over AM for our voice transmissions. AM was subject to easily being disturbed by other noise sources, such as static and lightning crashes, automobile spark plugs, etc. Also HF fading caused dramatic shifts in amplitude volumn levels. FM is much more immune to such RF noise disturbances. It also exhibits the "capture effect" which allows receivers to lock onto the strongest signal and ignore weaker ones. The same improvements of FM over AM voice are found for television.

FM Deviation: The amount of frequency deviation used depends upon the application. For our normal 2 meter / 70 cm FM voice rigs, the traditional systems used peak deviations of ± 5 kHz. In more recent years, to add more channels the FCC mandated that public safety agencies had to transition to Narrowband FM (NBFM) with only ± 2.5 kHz deviation. These radios are not capable of High Fidelity audio, but work perfectly fine with normal voice (300 Hz - 3 kHz). For TV, historically, it was designed to support High Fidelity audio up to 15 kHz. For VUSB-TV (or AM-TV), sound was sent out on a 4.5 MHz sound sub-carrier with ± 25 kHz deviation. FM-TV also uses 25 kHz deviation. FM broadcasting at 100 MHz band, uses even wider deviation of ± 75 kHz. Why use wider deviation ? It actually improves the signal to noise ratio, thus making audio (or video) clearer an more immune to RF noise. It also improves overall audio or video fidelity allowing a wider range of frequencies to be accurately transmitted. This is the reason the early days of analog satellite TV used ultra-broad-band deviations, because they were dealing with inherently weak signals on the earth from far distant satellites.

Pre-Emphasis: Pre-emphasis is another technique used in audio and video broadcasting to improve the received signal to noise ratio. It consists of boosting the high frequencies with a high peaking filter at the transmitter. Then in the receiver using the opposite de-emphsis low pass filter to minimize high frequency noise. Thus effectively allowing the use of a narrower band-width receiver. For TV audio with it's FM SSC, a simple R-C network is used with a 75 μs time constant. For the video signal, a more complex high peaking filter is used. For broadcast TV, the standard for pre-emphasis is defined in CCIR 405-1. The frequency response curve is shown in the following Fig. 15. Some FM-TV transmitters use pre-emphasis, while others do not. It should be noted that the cross-over frequency is not the same for all TV systems. The PAL system is different from the USA NTSC system.

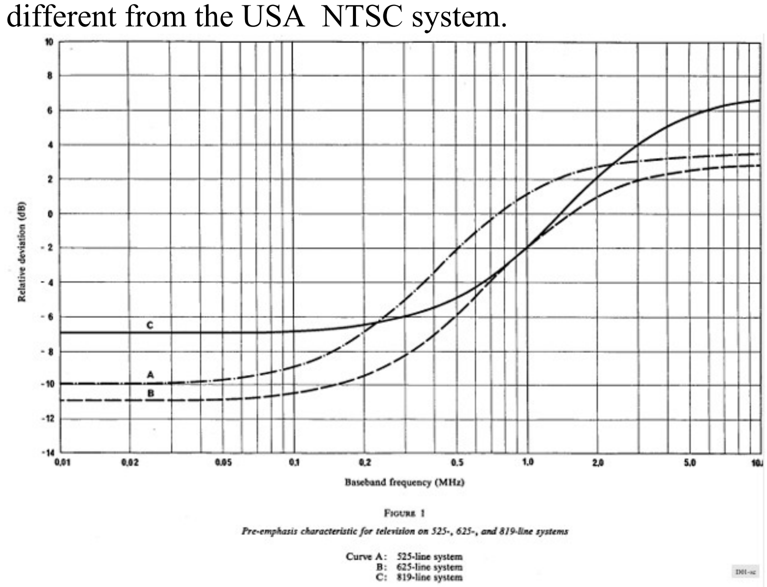


Fig. 15 Pre-Emphasis Filter frequency responses for TV, from CCIR 405-1

FM-TV Standards: VUSB-TV (or AM-TV) has a very strict set of standards set by the FCC. It is called NTSC. They include 6 MHz channel band-width, carrier frequency set to 1.25 MHz above lower edge, SSC set to 4.5 MHz above carrier frequency, Positive sync (i.e. max power on sync), color SSC at 3.58 MHz, etc.

Unfortunately, we can not say the same for FM-TV. Because FM-TV was not used for broadcast TV, each user was some what free in general to set his own standards. Thus some equipment will not be found to be compatible with others. Some of the key differences include the video deviation, video pre-emphasis (used or not), video polarity, and SSC frequency. Video polarity defines whether white picture content causes the carrier frequency to increase (or decrease). Because of these differences, for local compatibility, it was usually necessary for all neighboring hams to use the same equipment.

P5 - TV SIGNAL QUALITY REPORTING [4]

For analog TV reception, either for AM or FM, there are two types of major defects noticeable in the displayed pictures. A poor signal to noise ratio introduces what is most often described as "snow" in the picture, as seen below in Fig. 16. The other defect often seen is an additional weaker image seen displayed to the right of the correct image. This is due to "multi-path". It is the presence of a second rf wave arriving later in time from the direct path rf wave.

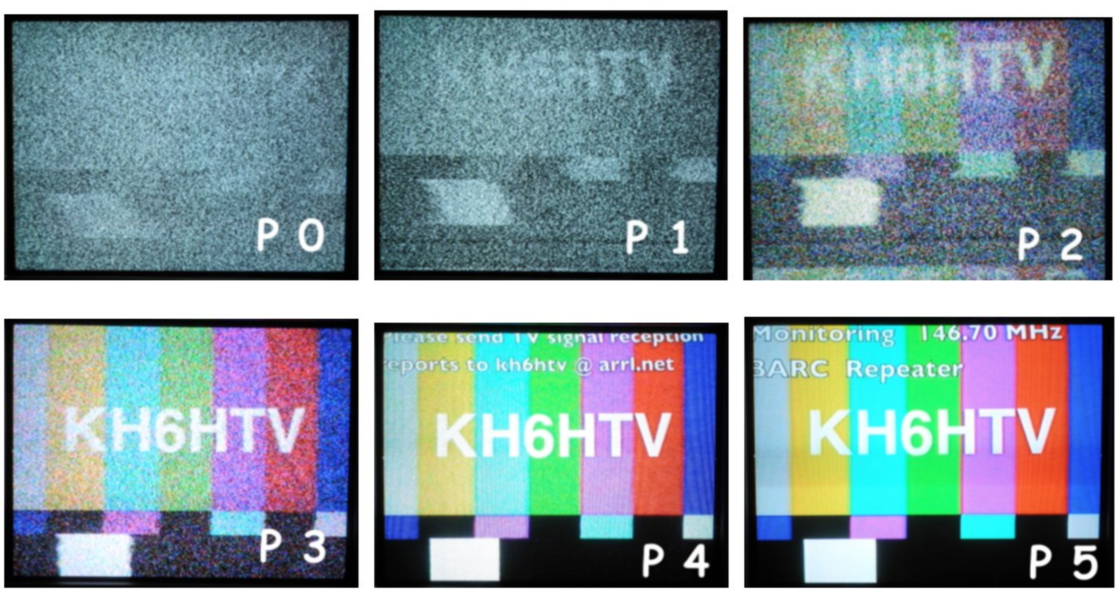


Fig. 16 ATV system of reporting Picture Quality

In HF radio we report signal reception using the RST method. R = Readability, S = Signal Strength and T = Tone (only used for CW). Thus a 5-9 report means perfectly readable with an S-9 on the S meter. For ATV we use a similar method for reporting the quality of the received image. We called it the P rating, i.e. Picture rating. Fig. 16 shows examples of various weak analog ATV signals and their respective P rating.

P0 Extremely weak signal. At the threshold of the receiver noise. Can only detect the presence of possible sync. No useable image.

P1 Very weak signal. Can detect presence of video buried in the noise. Mostly snow. Receiver often times has difficulty sync locking. Only very large block letters are barely readable, such as in a camera view of only the call sign on a stationary, automobile license plate. OK for DX reporting only.

P2 Weak signal. Lot of snow present in image. Black and White only. No audio. Can detect presence of people in the image and movement. Not a useable picture for routine, pleasurable viewing. Note: some excellent receivers might show color with a P2 signal. Then instead of white "snow", you will experience a shower of colorful confetti !

P3 Moderate signal. Still has snow present in image. Color lock. Audio is present, but noisy. Acceptable picture for people living in very rural areas watching broadcast TV.

P4 Strong signal. Very good color and audio. No snow or confetti. Some defects noted in picture quality. Almost full quieting on the FM audio.

P4.5 Strong signal. Only a very few, minor picture defects. A border line P5.

P5 Very strong signal. Perfect, noise-free, picture and audio.

Fig. 17 shows for VUSB (or AM) TV transmissions, to obtain a P5 picture requires an RF signal to noise ratio of S/N > 40 dB. For each P unit from P0 to P4, there is an increase in signal strength of 6 dB, i.e. the same definition as used for S units.

For NTSC, AM-TV, a very strong signal of at least -60dBm is required at the receiver's antenna input to give a perfect P5 picture.

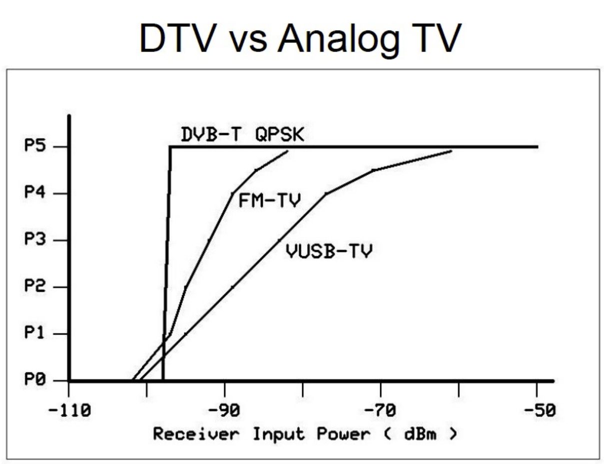


Fig. 17 P units vs. Received Signal Strength

For FM-TV, we notice a very dramatic improvement in signal quality at much lower signal levels. A full quieting, P5, picture results at a lower signal level of -80 dBm, a 20 dB improvement over AM-TV. This is a quite significant improvement.

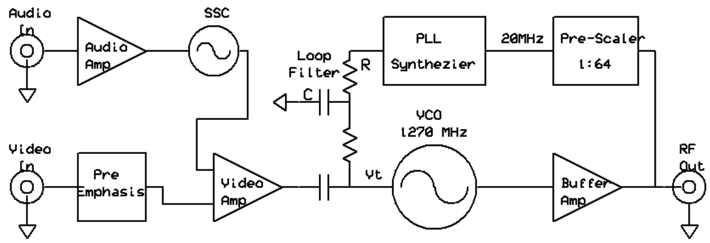


Fig. 18 Block Diagram for an FM-TV Modulator

FM-TV Transmitter: Fig. 18 shows the basic elements in building an FM-TV modulator. The heart of it is a Voltage Controlled Oscillator (VCO) to generate the video carrier frequency. It contains a Varactor Diode. The key characteristic of a varactor is that it's capacitance varies with applied reverse polarity voltage. Thus by applying various voltages the frequency of the VCO can be changed, i.e. FM modulated. Modern day transmitters use a frequency synthesizer design as shown by the additional components of the buffer amplifier, pre-scaler and PLL synthesizer which generates the tuning voltage, Vt The modulation is applied by AC coupling the modulating signal into the Vt port of the VCO along with DC tuning voltage. A TV transmitter includes both video and audio signals. The audio is transmitted using a sound sub-carrier with FM modulation. It's FM is also created by using a varactor on a VCO, but at a much lower frequency. For AM-TV, the SSC is at 4.5 MHz. For FM-TV there is no set standard and the SSCs may be anywhere from 5.2 to 6.8 MHz. A summing video amplifier is used to add the SSC to incoming video signal, the output of which then drives the Vt port of the carrier VCO.

The rf output of a typical FM-TV modulator is of the order of a few milli-watts. It is then boosted up to many Watts using RF Power Amplifiers. Most any amplifier can be used as linearity is not an issue with FM-TV. The most efficient amplifiers for FM service are class C amplifiers. TV Transmitter amplifiers should be rated for 100% duty cycle.

FM-TV Receiver: In the modern era, with FM-TV being in the microwave range, down-converters were used to put the TV signal on a lower IF frequency for demodulation. 70 MHz was a typical IF frequency used for FM-TV. Fig. 19 shows the typical block diagram for such an IF receiver.

All FM receivers, either for audio or video all started with a high gain chain of IF amplifiers called the Limiting amplifier. The purpose was to drive the final amp in the chain to full limiting thus converting the incoming variable amplitude sine wave to a fixed (i.e. limited) amplitude square wave. This helped eliminate noise due to amplitude fluxuations and RFI. The limited square wave then went to an FM detector. In the old, vacuum tube days, a special passive L-C circuit was used as the detector. There were several designs including Quadrature Detector, Foster-Seely Discriminator, Ratio

Detector and Slope Detector. With the advent of ICs, the detector of choice became the Phase-Locked Loop (PLL) detector.

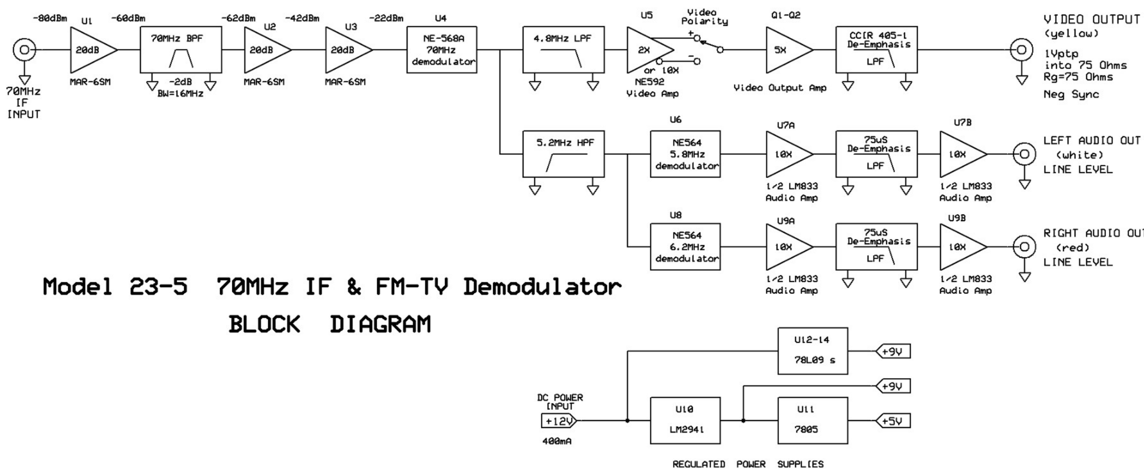


Fig. 19 Block Diagram for a typical FM-TV receiver

The block diagram shows using a PLL as the FM detector. The most commonly used IC for this purpose was the NE-568 from Signetics (later Phillips and then NXP). After the initial detection by the NE-568 from the 70 MHz IF signal, we now have base-band video, plus the FM SSC. To recover the audio, we then use a second PLL. For SSC detection the most commonly used IC was the NE-564.

Unfortunately, once digital TV became popular and analog TV, both AM and FM became obsolete, these ICs (NE-568 & NE-564) also became obsolete. You can no longer purchase them from the normal electronics distributors such as Mouser, DigiKey, etc. The only source found for them now are the vendors specializing in warehousing obsolete semiconductors. Plus as a result, one will have to pay a big premium in price over what they originally sold for.

FM-TV Equipment Available in 2026:

Fig. 20 The Ultimate Microwave Transceiver for FM-TV, ICOM IC-905

IC-905: For hams looking for the ultimate in equipment for doing FM-TV on the microwave bands, they need to look at the recently introduced ICOM model IC-905 microwave all-mode transceiver. In addition to doing CW, AM & FM voice, SSB, and D-Star it also includes FM-TV. It covers the 2m, 70cm, 23cm, 13cm, 5 cm and 3 cm bands. For 3 cm it requires the optional 10 GHz module. Current price is $2.7K, plus $1.2K for the 10 GHz module. There have been several product reviews of the IC-905 in the ATV Journal (available at www.kh6htv.com) [5]

Fig. 21 KH6HTV Video FM-TV products 23cm modulator (left), 23cm down-converter (middle) and 70 MHz IF & Demodulator (right)

KH6HTV Video: I developed back in 2012 time frame equipment for the FM-TV market, focusing on the 23cm band. I am still able to build it today. The products are shown in above Fig. 21. The modulator is frequency synthesized on three, user programmable channels. RF output power is +17dBm. The down-converter likewise is frequency synthesized on three, user programmable LO frequencies. 20dB conversion gain and 1 dB NF. The 70 MHz IF and Demodulator and also the Modulator are fully customizable to be able to accomodate most all variations of FM-TV standards. Unfortunately, due to the use of expensive, obsolete ICs and custom, one build at a time hand construction, these are expensive units. Current prices are in the $400 range for each unit.

DRONE - 5.8 GHz FM-TV Gear

Currently, here in 2026, the best, and least expensive solution to do FM-TV for hams is to use the equipment offered for the mass consumer drone market. I wrote an article in the June, 2026 issue of the ATV Journal [5] discussing this option in detail. Here is an shortened, edited version.

Back in the "Good Ole Days" of analog (antique) ham TV, we mainly used FM-TV on the higher microwave bands above 70 cm. Some ATV repeater groups still support FM-TV.

But the current issue for newer hams wanting to also do FM-TV is where to find the gear to do so ? ? ?

Fig. 22 Receiver & Transmitter

5.8 GHz: Well, essentially the only FM-TV gear presently commercially available is on the 5.8 GHz band. We have written about it a lot in previous issues of this ATV Journal. It is intended for the mass consumer market to provide video from drones. The key buzz word for Google searches is **FPV** or First Person View.

For example, go to Amazon and type in "5.8 GHz FPV Video Transmitter". You will find a large selection of products to chose from. One in particular which is my personal favorite is a transmitter / receiver pair with the model numbers of TS832 & RC832. In years past, they sold for the ridiculously low price of only $30. Current Amazon price is about $55 for the pair. Still a great bargain for what you get. For anyone wanting to get into ATV on the cheap, this is the way to go.

Both units are frequency synthesized and are pre-programmed for 40 channels. They range from a low of 5658 MHz up to 5945 MHz. Our 5 cm ham band is 5650 to 5925 MHz. A portion of it is shared with unlicensed Wi-Fi, etc. users. Here in Boulder, we have picked Channel 3-2, 5.685 GHz, to use for simplex operations and have found it to be clear of Wi-Fi RFI. Also, for our W0BTV-TV repeater's 5 cm FM-TV, 24/7, beacon transmitter, we are using Channel 3-6, 5.905 GHz.

The transmitter puts out a robust 600 mW of rf power. The receiver we have found to be extremely sensitive. With line of sight rf paths, we have made 2 way, 5.8 GHz, contacts over long distances up to 50 miles. We have even received signals from our TV repeater up to 70 miles away.

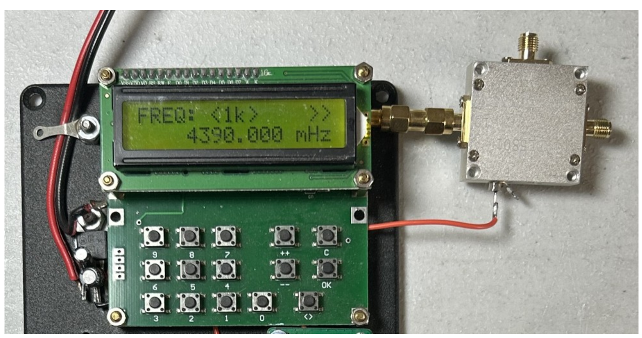


Fig. 23 Frequency synthesizer LO and Active Mixer for up/down conversion

OK so what about the lower microwave bands ? I have used this simple arrangement in previous issues of our ATV Journal as a mixer. The local oscillator (LO) consists of a low cost frequency synthesizer using an Analog Devices, ADF-4351. It covers from 35 MHz to 4.4 GHz. The mixer is an Analog Devices ADL-5801. It is an active mixer covering from 10 MHz to 6 GHz. It can be used for either up or down conversion. It's LO port can be driven directly with 0 dBm from the ADF-4351 as shown in the photo.

So using this simple LO/mixer I was able to down-convert to the 23cm band the rf signal from the 5.8 GHz TS-832 transmitter and receive it successfully using my 23-7 /23-5 23cm FM-TV receiver. Likewise, I was able to easily up convert a 23 cm FM-TV signal from my model 23-8 modulator up to the 5.8 GHz band and receive it successfully on the RC-832 receiver. The ADL-5801 mixer had -12 dB down conversion loss and -20 dB up conversion loss.

Standards for TS832 & RC832 ? Hams have asked what are the technical standards for these 5.8 GHz items ? There are no complete specifications given with them. So, now having the ability to compare them against some known gear, I was able to now give some answers.

Pre-Emphasis: Most FM-TV gear used pre-emphasis to enhance the receiver's sensitivity. There were however different, non-compatible standards used for NTSC vs. PAL systems. I found that the 5.8 GHz gear does NOT use pre-emphasis / de-emphasis. Instead it has a flat frequency response. It will thus work with either NTSC or PAL video signals.

Sound Sub-Carrier: For broadcast, AM (VUSB) TV, the standard sound sub-carrier (SSC) was 4.5 MHz with 25 kHz deviation. For FM-TV, the SSC used was not totally standardized, but was typically a bit higher in frequency. I found the 5.8 GHz gear used 6.5 MHz for it's SSC. The SSC level was set at -25 dBc.

Video Deviation: Most USA ATV repeaters used 4 MHz deviation for FM-TV. This was a more complex measurement to find out the deviation of the 5.8 GHz gear. My first test was to observe the spectrum of the TS832 and compare it to that of my model 23-8 which was calibrated to be 4 MHz deviation. This test was performed at 1255 MHz with the TS832 signal being down-converted from 5645 MHz. Using the Bessel Null method, I found the TS832 used a lower deviation. It was set to 2.65 MHz deviation.

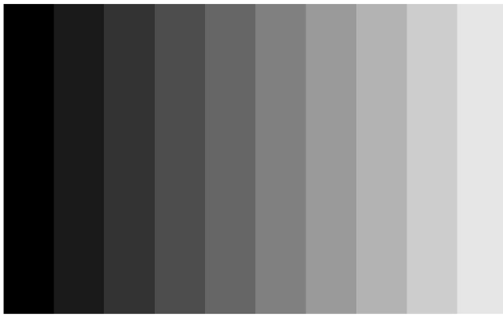
CONCLUSION: With a knowledge of the standards used for the 5.8 GHz FM-TV gear, hams should now be able to also use them along with LOs & mixers to generate and receive FM-TV signals on our other microwave ham bands.

==

TV TEST PATTERNS:

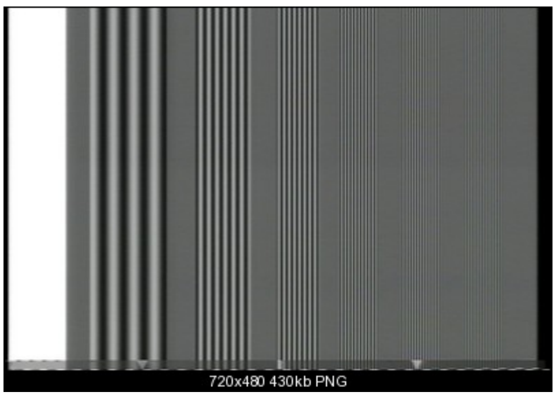
TV engineers and technicians have found using standardized test patterns useful for testing and alignment of TV systems. Here are a few of the older test patterns used for analog TV, Fig. 24. A google search on the internet will come up with a lot more test patterns.

The most useful for aligning a simple ATV, transmitter is the G**ray Scale** test pattern. It includes both solid black and solid white levels to set properly the modulation depth. It also includes a staircase of equal level steps with different shades of gray, useful for looking at the linearity.

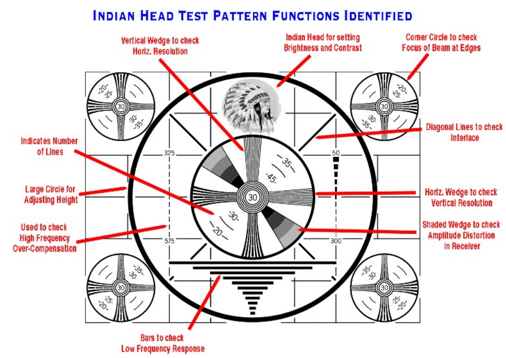


Gray Scale - Stair Case
black to white

Color Bars



Multi-Burst



Indian Head

Fig. 24 NTSC TV Test Patterns

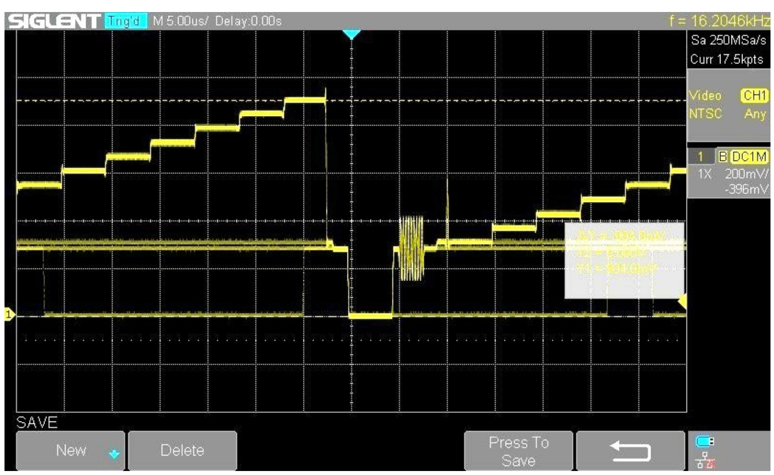


Fig. 25 Gray Scale Test Pattern waveform as measured on an oscilloscope. One horizontal line is shown. 5µs/div. The horizontal sync pulse followed by the 3.58 MHz color burst is seen in the center.

The **Color Bars** test pattern also include both white and black levels, plus intermediate step levels with the different colors. Useful for determining color purity. Also great to use for your ham TV station ID by super-imposing your call sign over the color bars.

Fig. 26 Station ID

The **Multi-Burst** test pattern is useful as a quick check of frequency response. It starts with a step up to solid white. It is then followed by separated short bursts of rf sine waves of equal amplitude and increasing frequencies, centered at the 50 IRE level. They are: 0.5, 1.0, 2.0, 3.0, 3.58 & 4.2 MHz

The **Indian Head** test pattern is of mostly historical interest. It contained a wealth of test patterns in it. It's primary use was in the old vacuum tube, CRT receiver days when the service tech needed to make major adjustments in the focus, astigmatizm and geometry of the CRT display tube.

TV TEST EQUIPMENT:

There are several pieces of ham shack test equipment useful for testing and aligning your analog ATV gear. They obviously include a video camera and a video monitor as a bare minimum. Other items include: an oscilloscope, audio signal generator, rf signal generator, spectrum analyzer, rf power meter, etc. In the past, well equipted TV shops also included from Tektronix a TV waveform monitor, a vector signal analyzer, and a video waveform generator. Your oscilloscope can function well as the waveform monitor.

There are several low cost solutions to making a video test signal generator. Several video accessories such as an HDMI video splitter, etc. now create a color bar signal whenever they detect no valid incoming video signal. A very useful, low cost ($40) device for the shack is what is called a "Media Player". It reads from a USB memory stick either picture (jpeg, etc) or video (mpg, etc) files and plays them automatically. It has both HDMI and composite video outputs. To create a stationary test pattern, copy onto your USB memory stick only one single picture file, such as those shown above in Fig. 24.

Fig. 27 NTSC Test Pattern Waveform Generator

Fig. 27 shows my NTSC waveform test generator. The blue module is the Media Player. I found that it's composite video signal output was quite low (0.3V ptp) and did not meet the standard of 1.0V ptp. I thus took the HDMI output from the media player and ran it to the black module, which is an HDMI to composite video converter. It gave me almost the correct 1.0 V level composite video which is being displayed on the video monitor.

Your TV camera can also be used as an alignment tool. Set it up on a fixed tripod looking at a fixed scene. The scene could in fact be a well lighted paper TV test pattern. The scene should have some very bright white features along with some extremely black features in it. You should then use your oscilloscope to test your camera's video output to verify that it is putting out standard 1.0 V ptp video into a 75 Ω load. If it's output is too "hot", i.e. too high, it is best to make a simple attenuator to pull it down to the standard 1.0 V level. \

FM-TV Adjustments & Calibration:

For either an audio or video FM transmitter, one of the key adjustments is to set properly the deviation. Full details on the theory and how to do this are explained in my application note, AN-14, "FM Transmitter Deviation Adjustment & Calibration" [6]

In quick summary, the Bessel Null technique is used to set deviation. For 4 MHz deviation FM-TV if using a flat frequency response with no pre-emphasis, you use a 1.663 MHz sine wave. Set it's amplitude to precisely 1.0 Volts ptp into 75 Ohms. Connect it to the transmitter video input port. Set the transmitter video gain to minimum. Monitor the rf spectrum on a spectrum analyzer. Watch the center, carrier frequency. Slowly increase the video gain until the center frequency reaches a null. See Fig. 28.

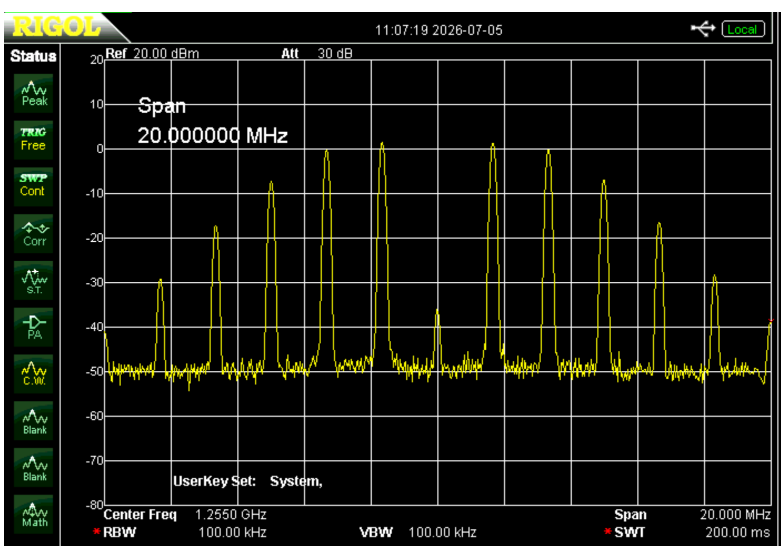


Fig. 28 Bessel Null spectrum for an FM-TV transmitter set to 4 MHz deviation. 10dB/div & 2 MHz/div. Input was 1.0 Vptp, 1.663 MHz sine wave.

GET ON THE AIR ! This completes this application note. Now it is time for you to get on the air with FM-TV and share videos with your fellow ham ATV buddies.

REFERENCES:

1. "ATV Handbook - an Introduction to Amateur TV", Jim Andrews, KH6HTV Video app. note AN-55b, rev. March, 2026, 40 pages

2. "Amateur Analog AM Television", Jim Andrews, KH6HTV Video app. note, AN-75, April, 2026, 27 pages

3. ARRL Handbooks, published annually. see in particular the chapter on Modulation methods.

4. "P5 - TV Signal Quality Reporting", Jim Andrews, KH6HTV Video app. note, AN-5a, rev. Sept 2019, 3 pages

5. ATV Journal, newsletter published since 2018, monthly or more often, distributed free via e-mail. Archived issues available at www.kh6htv.com

6. "FM Transmitter Deviation Adjustment & Calibration", Jim Andrews, KH6HTV Video app. note, AN-14, Aug. 2012, 4 pages