

AM VERSUS FM TELEVISION SIGNALS

FREQUENCY MODULATION FOR AMATEUR TELEVISION

Many amateur television enthusiasts are experiencing new and satisfying results using frequency modulated television systems. Those of us that have been operating AM amateur television have suffered for the last forty years with the many decisions that were made before WW II for American commercial television. Due to the fact that so much commercial equipment has been available, it has actually hindered the development of new video and RF systems for amateur TV.

In the video field, the new Multiple Analog Components (MAC), have begun to replace NTSC for color transmission. In the RF field, the FMTV mode has begun to replace the old AM method of transmitting video information. USA amateurs are late in adapting this mode to their experimentation. Commercial satellites, broadcast TV relays, and the military are already using FM for video transmissions. Let us further examine some of the problems with AM television transmission.

The 70 cm band is the lowest amateur band where television transmissions can be made with full wide when the subcarrier sound is considered part of the video signal. This video signal is applied to a 70 cm transmitter with careful control of the linearity of the system. Since we are using amplitude modulation with the sync pulses maximum without sync clipping. Due to the fact that most of us solid state amplifiers presents a problem due to the non-linearity of the amplifiers. This problem has been solved somewhat by pre-amplifying the sync pulse to greater height than normal. When the compression occurs on this overstretched sync pulse the signal will be reduced to the normal relationship of 40 units of sync and 100 units of video. This results in an average transmitter power much less than maximum transmitter power.

Over the last 20 years there has been great growth in the use of FM voice repeaters. Tests have shown that single sideband (ssb) on the VHF bands is superior in transmission efficiency over FM. Never the less FM has won out because of the ease of generating RF power with Class c non-linear amplifiers. If SSB had been used, the amplifiers would have to have been linear and would suffer the same problems that were discussed in the previous paragraph concerning AM television.

If FM is used for amateur television, there will be no need to worry about sync clipping or reduced is the maximum that the amplifiers are capable of putting out. On 1200 MHz this is a real advantage since it is very hard to get much power into the antenna on this band. There are many other advantages and some disadvantages to FM-ATV but the advantages far outweigh the disadvantages.

The simplest FM-ATV transmitter is an oscillator with an electronic variable capacitor (varicap) in the tuned circuit. Video is placed on the varicap and the resulting signal from the oscillator is FM modulated. The output frequency is not crystal controlled but many experimental beginning systems operate in this way. Due to the fact that the

bandwidth is not noticeable. Some improvement has been made in RF components these last few years permitting nearly drift-free operation on the 900 and 1200 MHz bands.

The bandwidth of an FMATV transmitter is determined by the amplitude of the video signal. The peak video voltage determines deviation of the carrier. This total bandwidth is calculated by the following equation:

$$B=2(ft+fs)Hz$$

Where f_t is the peak deviation of the carrier and f_s is the highest instantaneous frequency of the modulating signal.

Receiving FM-ATV is not quite as simple as receiving AM ATV because the TV receiver has little capability of receiving the FM modulated TV signal. IT is true that slope detection of the signal is useful for some experimental testing, but it is best to build a receiver that is dedicated to receiving the FM-ATV signal. This means that the receiver will have video and audio outputs that drive an analog computer monitor or the video and audio inputs of a video tape recorder connected to a television set.

The signal to noise advantages of FM is determined by the modulating index (M). This modulating index is calculated by the following formula:

$$M = \frac{\Delta f_t}{f_s}$$

Later we will show how this modulation index results in signal to noise improvements over conventional AM-ATV.

The bandwidth of a typical signal with a normal color NTSC video source can now be calculated. If the deviation is chosen to be 4 MHz and the maximum video frequency of 3.5 MHz, the resulting RF bandwidth is 15 MHz. For this reason FM-ATV is mainly useful in the 900 and 1200 MHz bands. Even though theoretically the bandwidth of any FM signal extends to infinity, in practice it disappears much sooner than expected. The spectrum as viewed on a spectrum analyzer does not show much difference in bandwidth than a normally modulated AM system. The amateur television enthusiast need not worry about interference in the average installation.

Questions will be raised in the readers mind about reducing the deviation to reduce the bandwidth. This can be done but the signal to noise improvements over AM-ATV will be reduced likewise. This should be experimented with to determine what the stations can best use.

Another effect that shows up in FM-ATV transmissions is the angular noise effect. Figure 1, shows the resulting noise from FM detection as a function of modulating frequency. The curve show that as the modulating frequency goes up that the noise

increases. Since a video signal has frequencies extending from 60 Hz to 3.5 MHz, the higher frequencies will suffer from more noise than those at lower frequencies in the detection system. This has been effectively solved by using a principle called Pre-emphasis and the complement in the receiver De-emphasis. Pre-emphasis makes it possible to increase the amplitude of the smaller higher frequency video signal in order to deviate the carrier more than normal. This can be a passive circuit in the video path both in the transmitter and receiver. All FM-ATV systems use this method of preserving the high fidelity of video transmission.

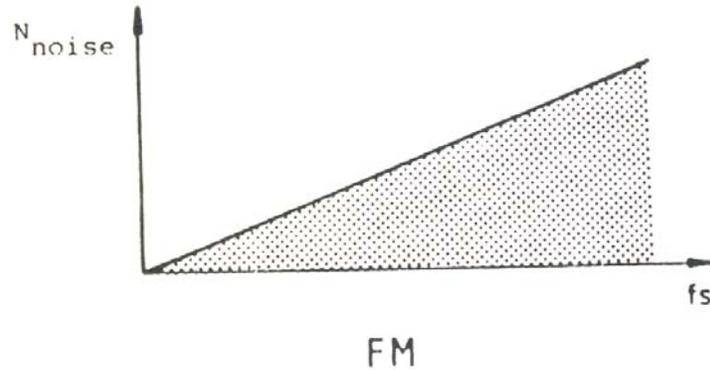


Figure 1: Triangular noise spectrum of a demodulated FM-ATV signal.

The commonly used pre-emphasis and de-emphasis circuits for a 525 line system are shown in Figures 2 and 3

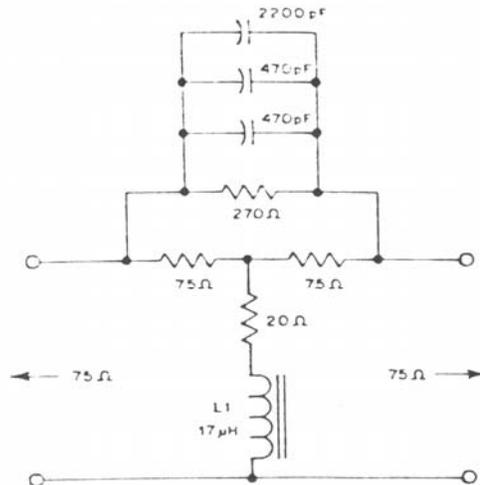


Figure 2: Pre-emphasis circuitry used in the FM-ATV transmitter.

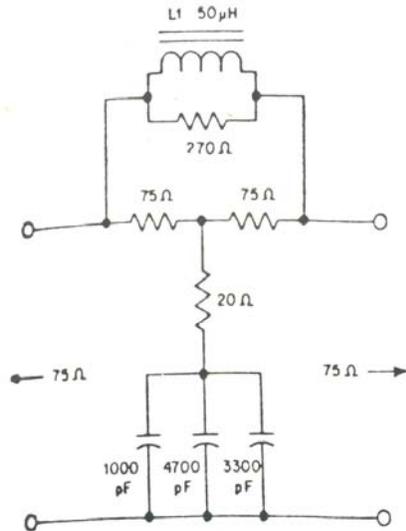


Figure 3: De-emphasis circuitry used in the receiver.

The pre-emphasis curve is shown in Figure 4. It is for the 525 line system used in USA and other 60 Hz power countries. The de-emphasis curve restores the video response to the original level before transmission.

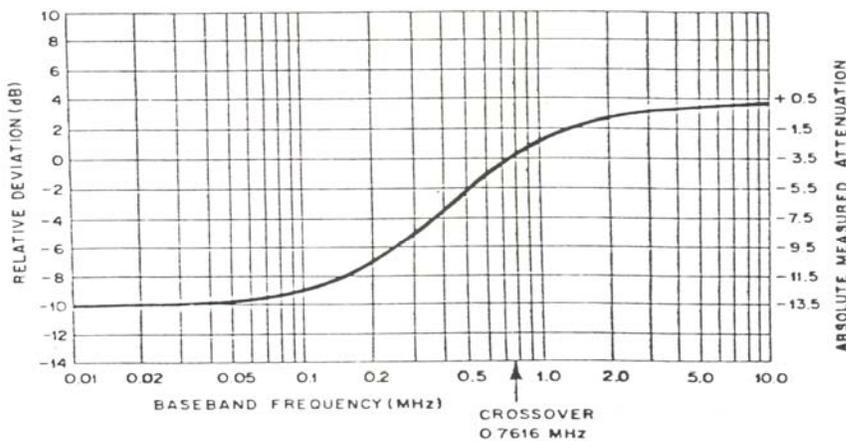


Figure 4: Pre-emphasis curve for 525 line system.

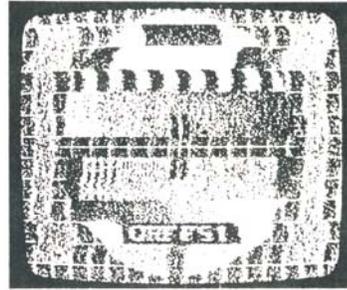
Transmitters for generating an FM-ATV signal have been difficult to build in the past. Recently there has appeared on the market a new frequency divider chip that permits simple construction of a milliwatt exciter for any UHF or microwave frequency up to 2 GHz. The circuitry works on the desired output frequency.

The oscillator is buffered by an integrated circuit and its output voltage is connected to a Plessey SP5060 divider chip. This chip has a division ratio of 256. It also includes a phase detector, crystal oscillator circuitry and other circuitry needed to lock the two frequencies together. Since the LC oscillator is varactor tuned, it's an easy task to connect the error voltage detected between frequency divided free running LC oscillator and the

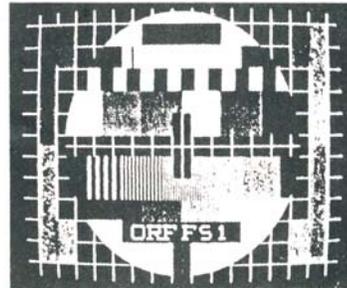
crystal controlled oscillator to the varactor controlled oscillator . This results in a crystal controlled frequency 256 times the frequency of the crystal. The FMing of the loop with video results in a crystal controlled FM-ATV signal.

The circuitry is simple. The first time that the basic circuit has been published for use in an amateur FM video transmitter was in VHF Communications, January 1989. This output of the buffered oscillator is about 10 mW. This can be used to drive an ICOM brick, SC-1043, that can amplify the 10 mW to 5 watts on 1200 MHz. This is sufficient to drive most larger amplifiers such as the HY-SPEC 200 watt 2C39 amplifiers giving several hundred watts output. The complete exciter is shown in Figure 5 and 6. Boards and all parts are available from the author.

FM TV SIGNALS



C / N = 10 dB: Picture contaminated by noise



C / N = 30 dB: Noise just discernible

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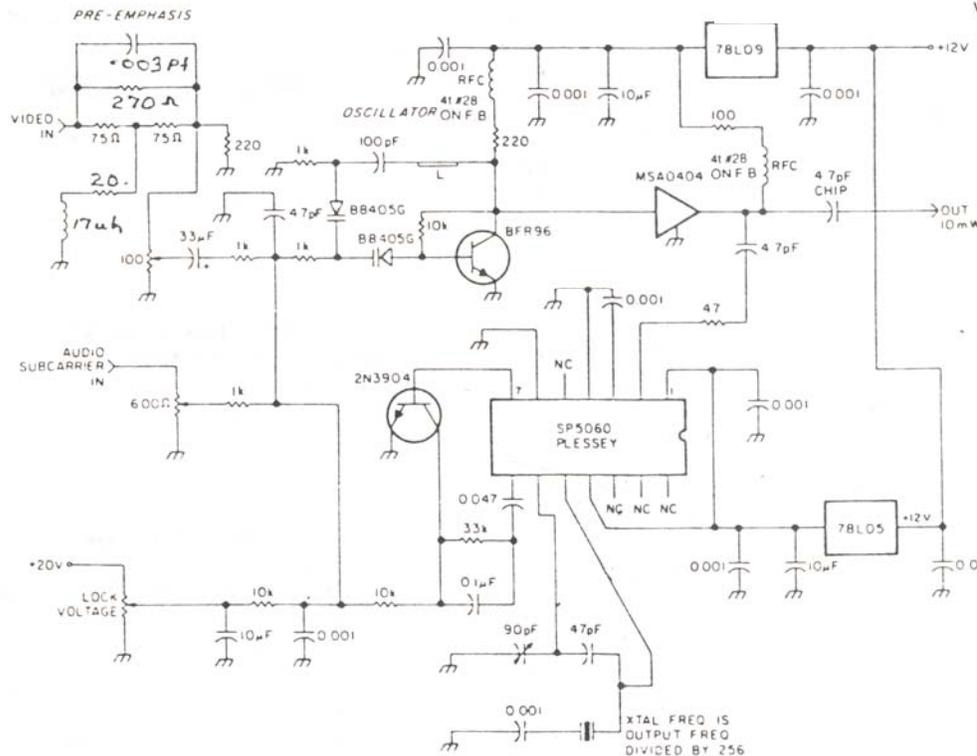


Figure 5: Exciter for generating FM-ATV.

another signal on the other side of the injection oscillator frequency. As an example, if the IF frequency was chosen as 50 MHz, the desired signal is 1250 MHz, and an oscillator frequency of 1200 MHz, the image is 1150 MHz. Any signal on 1150 MHz will be reduced only by the front end selectivity. The selectivity at 1200 MHz may not be very good. For that reason a high IF frequency of several hundred megahertz would be more desirable.

A higher IF frequency (479.5 MHz chosen by the Europeans) is a better choice providing a method of detecting the FM-ATV signal can be found. The normally used PLL used in satellite receivers will not operate much above 50 MHz. Two choices of integrated circuits that may be usable at 479.5 MHz are the SL 1452 and the NEC 1477c. The most easily obtainable integrated circuit for FM-ATV detection is the NE (SE) 564. It is used at an IF frequency of 50 MHz even though the previously discussed image problem may be difficult to solve. Interference near the 1200 MHz band is minimal but if it is present it is overwhelming all over the band (radar transmitters operating at megawatt levels).

The recommended method of receiving FM-ATV is shown in block diagram in Figure 7. A down converter for the chosen band is selected to have an output IF signal of 50 MHz. There are several choices of designs. Since this chapter is devoted to FM-ATV in genera, no particular band will be emphasized since the circuitry described can be used on any band providing the correct down converter is connected to the front end. The only commercial choice known by the author is the Wyman Research Inc. down converter based on a circuit published in the BATC publication, No. 122. Wood Douglas has a commercial unit but it has become prohibitively expensive due to the pound/dollar ratio.

Building choices are found in back issues of CQ-TV and VHF Communications. Both magazine subscriptions are available from the author.

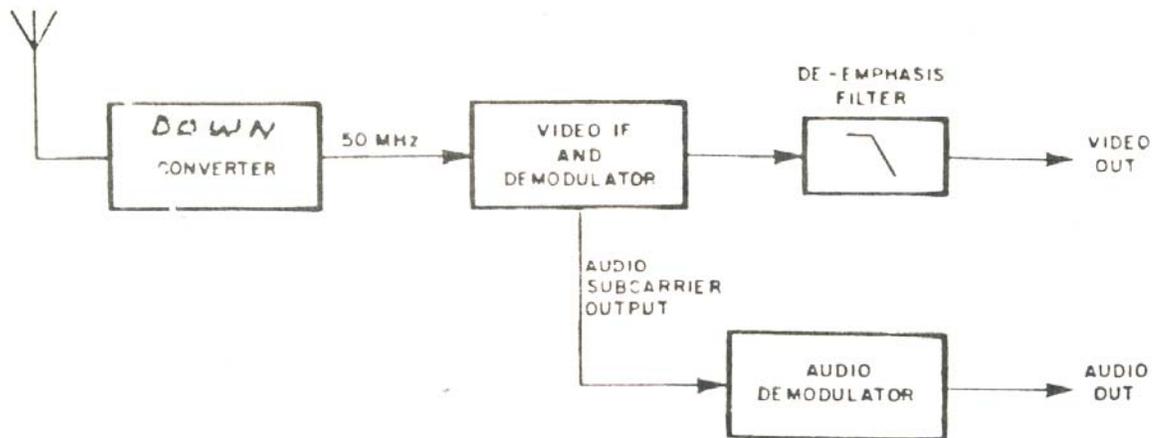


Figure 7: Block Diagram of a FM-ATV Receiver.

The down converter amplifies the incoming signal and converts the signal to an IF frequency of 50 MHz. The down converter should have about 20 dB gain. The resulting 50 MHz signal is amplified and detected by a phase lock loop circuit. This resulting video signal is amplified again and outputs to a 70 ohm line as 1 volt of video. The de-emphasis circuitry can either be internal to the IF strip or external. The audio detection is usually done by a separate receiver strip at the chosen subcarrier frequency. Normally the audio subcarrier (an audio modulated signal inserted as video) is either 6 or 5.5 MHz.

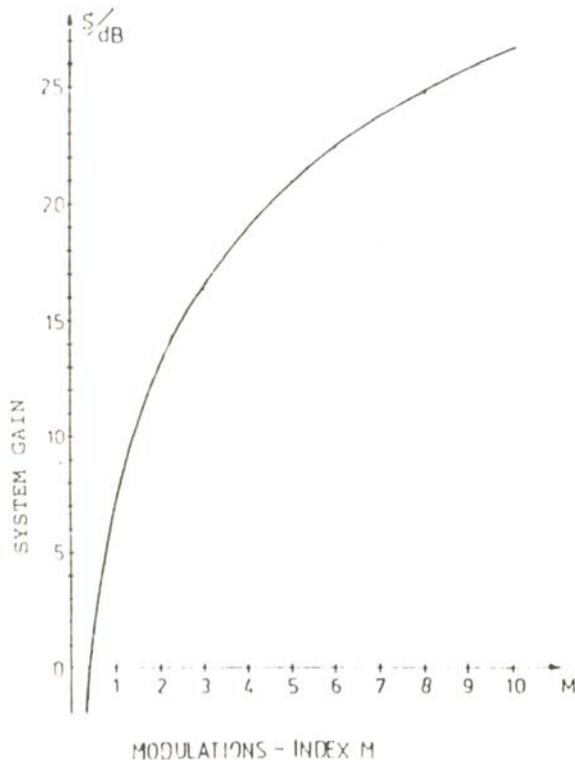
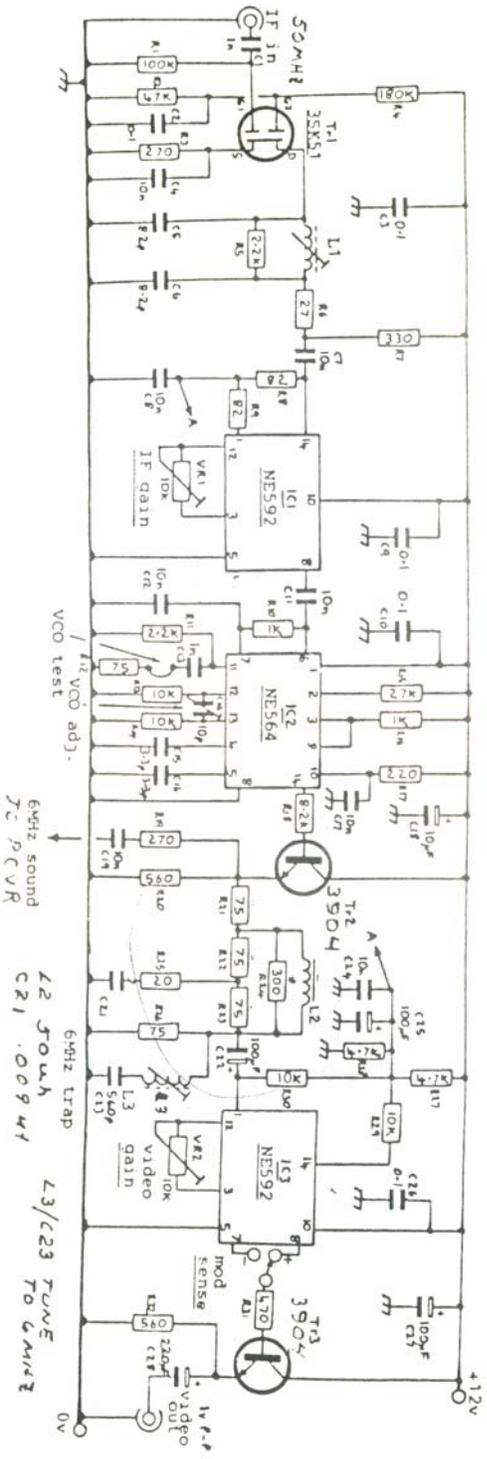


Figure 10: FM system gain over AM as a function of modulation index (M).

A very popular IF design has been available for several years from the British Amateur Television Club (BATC). Boards are available either from the author or Figure 8. It has a dual gate MOSFET front end. A NE 592 amplifier amplifies the 50 MHz signal where it is phase lock loop detected by a NE 564 integrated circuit. Following the detection of the FM signal it is de-emphasized by a passive circuit to restore the levels of the original video signal. A 5.5 MHz or 6 MHz sound trap is included to eliminate interference to the detected video. Finally the video signal is amplified by a NE 592 integrated circuit and outputted through an emitter follower. FM receivers have a polarity switch which can correct the video if it is sent upside down. This is different than AM-ATV where sync is always transmitted as maximum power. A SPDT switch makes it easy to reverse the video if a station is transmitting an upside down signal.



The main drawback of this receiver IF strip is the lack of good selectivity in the front end. There are presently some attractive filters being sold by Mini Circuits that could help solve the selectivity problem. This has not been tested by the author but plans are to include these in the design. The problems with the choice of a 50 MHz IF frequency have already been discussed. Hopefully the 900 MHz and 1200 MHz bands will not have too many strong images.

The sound receiver is a simple circuit that has been sold by Wood Douglas and volume control. The squelch is limited in its use but serves to quiet the receiver. The circuit is shown in Figure 9. Again boards and parts are available from Wood Douglas or the author.

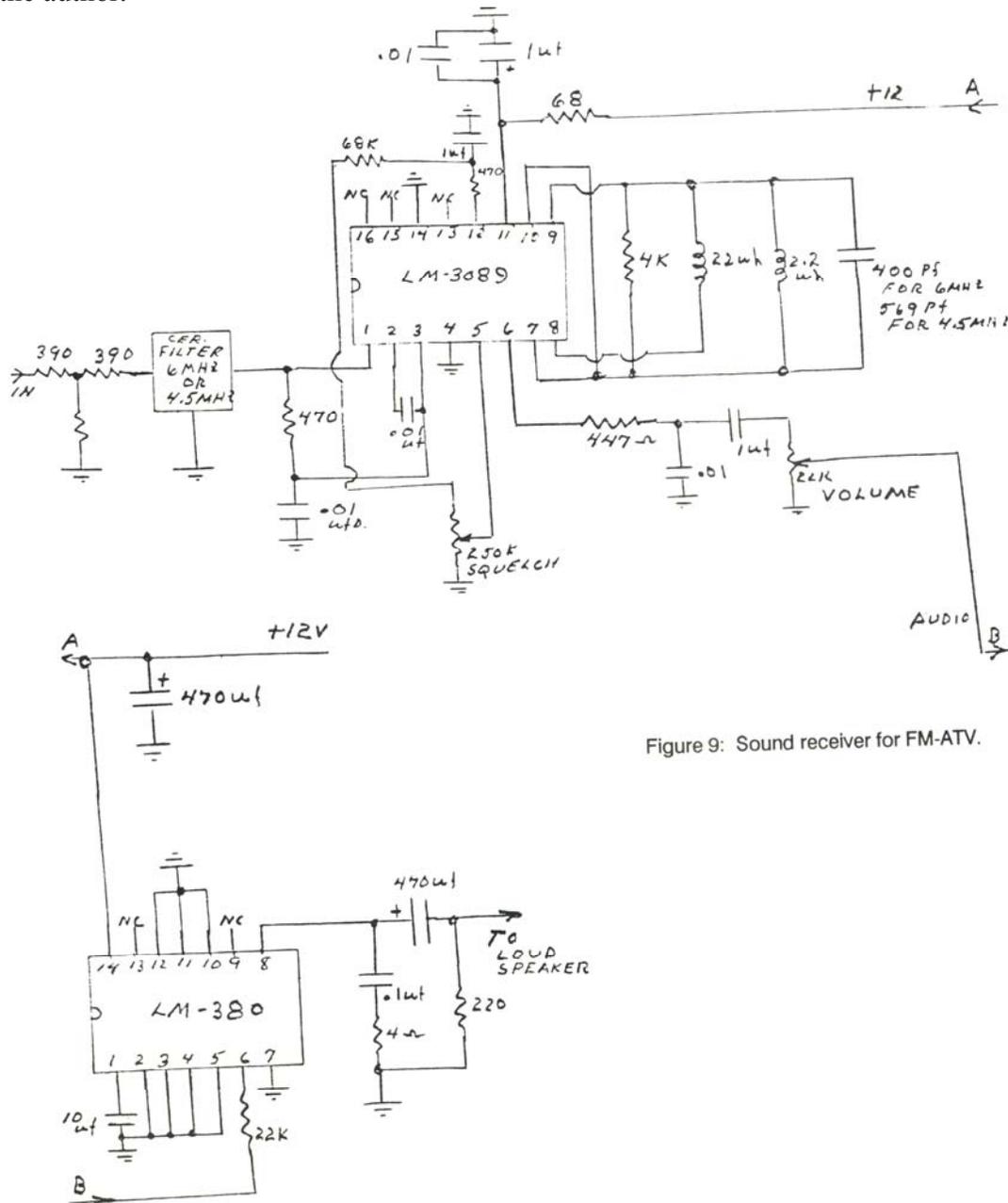


Figure 9: Sound receiver for FM-ATV.

ADVANTAGES OF FM OVER AM

The next question one asks themselves is: Why switch or add FM-ATV operation mode capability? Is it really worth the effort? Before we discuss the theoretical aspects of the change, remember that amateurs all over the world are using FM-ATV on the bands where adequate bandwidth is available. In our case this is all bands above and including the 900 MHz band. Satellites are using FM-TV as are the broadcast links for sporting events and special remote broadcasting. The military use it exclusively for remote control of bombs and surveillance. Let us examine the formula that tells why FM-TV is a superior method of sending video signals.

FM-ATV has several advantages over AM-ATV. In order to compare the two consider the following formula showing the expected theoretical gain of FM over AM. When the modulation index (M) exceeds 0.5, FM begins to show distinct system gain over AM. The formula normally used to calculate this gain is given below.

$$S=10 \log 3(M/m)^2$$

Where m is the modulation factor of AM and is taken as 0.8 in order to not cut the AM carrier off for sound purposes. M is the FM modulation index and a curve showing the expected gains as the modulation obtained from using FM is directly related to the amount of bandwidth consumed. For a 4.5 MHz video bandwidth and a frequency deviation of 4 MHz, (modulation index, M, of 1), the bandwidth calculates to be 17 MHz, by the formula, $\text{Bandwidth}=2(\Delta f + f_s)$.

The curve shown in Figure 10 is based on the previous formula. It shows that the system gain for an M of 1 is 6.7 dB. The use of pre-emphasis and de-emphasis will bring the system gain up by 14 dB. The system of special demodulators will increase the total system gain to 20 to 25 dB over AM-ATV. The threshold effect in FM systems occurs about 10 dB above the system. From 3 to 6 dB above the threshold the system cannot be improved by increasing power or receiver sensitivity because the pictures are already P5.

The advantages of FM-ATV over AM-ATV are: 20-25 dB better signal to noise ratio for FM over AM, less visible interference from other weaker stations, better color, simple transmitter construction, better compatibility with transistorized linear amplifiers just to name a few. All stages of the transmitter can be operated fully saturated or in Class C for maximum efficiency. Front panel transmitter controls can be minimized since there are no problems with sync. Clipping or there are no problems with sync. Clipping or video saturation.

The disadvantages of FM-ATV are few the largest being that a FM-ATV intermediate amplifier and detector must be built. The ordinary TV set can not be used except for preliminary testing with slope detection. The satellite receiver has much wider passband (26 MHz instead of 15 MHz) and consequently the signal to noise ratio resulting from its use is marginal but usable. Weak signal reception from very weak signals is poorer than AM due to the threshold effect. This threshold is about 10 dB

above the receiver noise. As soon as the picture becomes visible, color is present immediately, unlike AM-ATV.

On the other hand, FM has immunity from fading since it uses hard limiting. This makes it possible to have better locked pictures during fast fading periods. Multipath effects may result in negative pictures in severe multipath situations. This effect is variable and probably is not FM-TV proves that the multipath effect between ground reflections and direct path does not deteriorate the resulting video picture to the extent that it is a problem.

Despite some unfortunate negative thinking by a few over the years within the ATV community. The SPECCOM Journal and The USATVS here in America, have been instrumental in encouraging FM HAM-TV operations and building. Because of this leadership, many ATV operators have kept an open mind and have taken serious interest in this relatively as yet, unexplored mode of visual communications. After all, that is what Amateur Radio is supposed to be all about, isn't it?