20 Imaging Techniques

Although amateur radio has a long history of audible communication, whether by voice or Morse tones, it has also had a following of enthusiasts exploring the visual facets of the hobby. Imaging, whether used for information such a weather maps or used for live television pictures, is simply the name for viewing a picture at one location that has been produced at another, remote location. The imaging side of the hobby has many aspects, ranging from the reception of pictures from weather satellites to the transmission and reception of very high quality digital 'live' television signals.

It is a common misconception that it is expensive and complicated to get involved in amateur television, in fact the opposite is true. The spin-off of domestic analogue and digital broadcasts has been a surplus of very cheap receiving equipment which is ideal for conversion to amateur use. The transmitting equipment is less accessible and is one of the few remaining areas where real experimenting and ‘home-brewing’ is still common place. Putting technicalities aside, it is still quite feasible to build a complete television station for less than the cost of a new handheld VHF rig.

Broadly speaking, there are two categories of amateur television, the narrow bandwidth modes which typically convert images to sound so they can be sent over voice channels and wide bandwidth modes which may occupy many megahertz and are therefore only allowed on UHF frequencies and above. From a picture perspective, the narrow band modes can only transfer still images whereas the wide band modes can carry enough information to convey live colour pictures and even stereo sound in some cases.

Each of these categories can be further divided into transmissions using analogue techniques and those using digital modulation. 'Digital' can be a scary word to people familiar with things that can be measured with a meter and dazed by 'new technology'. It is worthwhile reminding them that the first digital long distance transmissions were made by Samuel Morse in 1843, more than 30 years before the telephone was invented and 50 years before the first man-made RF hit the airwaves!

SLOW SCAN TV AND FACSIMILE

These are also known as SSTV and Fax respectively; they are technically very similar. The bandwidth required to send information is proportional to the rate it is sent and both these modes slow that rate to a pace that allows the information to be encoded as low frequency tones. By reducing the rate, the ability to send pictures quickly enough to be seen as motion video is lost, some modes can take more than a minute to send a single picture (a frame). In contrast, normal broadcast TV and fast scan modes send at 25 or 30 frames *per second*. However, for sending still pictures, these modes are perfectly adequate. Because they convert the picture to tones within the voice frequency range, it is possible to transmit them by simply feeding the tones to a transmitter microphone socket. The transmission is frequently FM on the VHF/UHF bands and SSB on the HF bands. It should be noted that throughout transmission the audio level will remain high and therefore an SSB transmitter will likely run at peak power for several continuous seconds (high duty cycle), it is advisable to 'back off' the output power to prevent over stressing the PA stages.

SSTV and Fax both work in the same way, only the scan frequency and number of scan lines distinguishes them. The picture being sent is divided into horizontal lines and each line is preceded by a synchronising (sync) pulse. The sync pulse is sent as a particular audio tone then the line of picture is scanned from left to right. As the scan point traverses the picture, the brightness at that point is converted to another tone. A low tone represents a dark part of the line and high tone a bright part. The shades of grey between them produces a tone proportional to the brightness.

For colour modes, each line is scanned three times and the brightness of the three primary colours, red, green and blue are sent in the same way as grey. When the end of the scan line is reached, the next one starts, again with a sync pulse but this time the line is a little further down the picture. When all the lines have been scanned, the bottom of the picture has been reached and (normally), the transmission ends.

At the receiving station, the tones are taken from the receiver, either through the headphone socket or another audio outlet. The sound is filtered to extract the sync pulse tones and these provides a reference point to align the start of each line. The following tones are converted back to an image, the higher tones producing a brighter trace than the low ones.

In the same way as the sending station scanned the picture to produce tones, the receiving station converts them back again and if all goes well, the same picture is reproduced. For colour pictures, tones conveying the red, green and blue content of each line are sent in sequence and then overlaid to reproduce a composite of the three before moving to the next scan line.

The sequence of colours, the scan rates and tone range have to be the same at the transmitting and receiving stations and for this reason, standards have been defined. Unfortunately, there are around ten different standards in use but two, the 'Scottie1' and 'Martin1' seem most popular. The majority of SSTV and Fax stations use computers both to generate tones and to decode them back to pictures again and there are many software applications around to do this.The screen shot in **Fig 20.1** was taken from MMSSTV [1] written by JE3HHT.

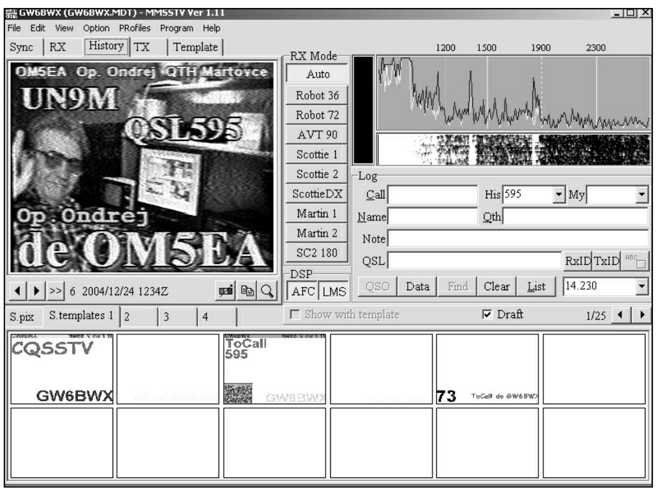

Fig 20.1: The slow scan window of JE3HHT’s MMSTV program

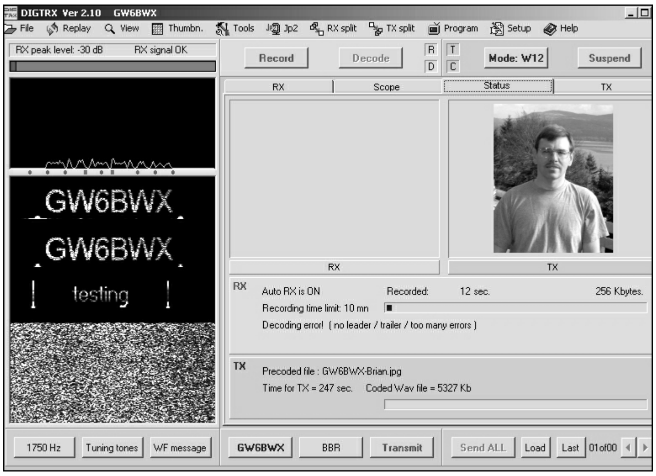

Fig 20.2: The DIGTRX control window

In most cases, all that is needed to get on the air with these modes is a cable to link the computer's sound system to the rig microphone and headphone sockets.

In days of old, it was common practice to decode SSTV with quite complicated audio filtering circuits. Typically, a narrow band filter would separate the sync signals from the rest of the tones and a filter with a linear gradient across the voice spectrum would convert the picture tones to different voltage levels. The voltage samples then had to be stored in order that the picture could be built up over its 15 seconds transmission duration. Originally this was done with long-persistence phosphor CRTs and later with semiconductor memories.

The advent of the personal computer brought about many changes to SSTV, making the process of creating, decoding and storing the pictures much easier. Images are now usually pre-prepared using scanned photographs or digital art programmes. They are converted to tones using synthesis techniques, utilising the capabilities of the computer's sound card. Decoding is achieved by performing a Fourier analysis of sound samples, a method which helps to isolate the dominant frequencies from the background noise to give a better signal to noise ratio. Storage while viewing is in the computer's video memory, and optionally the images can be permanently stored on disc or printed on paper.

A recent development, similar in speed to the method described earlier is 'DIGTRX' by PY4ZBZ [2]. It is a system of sending data files or pictures by using a different tone for each of the eight bits in each data byte. The bytes are sent one after another and the pattern of bits in each byte produces up to eight tones which are spaced equally in the voice frequency range. It can therefore be sent in a narrow bandwidth in the same way as conventional SSTV. A degree of pre-processing has to be done to the bit pattern before the bits are converted to tones to lessen the effects of errors and to produce a more even spread of tones. Take the case for example of a long string of zeroes being sent, which happens frequently in data transmission, without any bits being set, no tones would be produced and no transmission would take place. The pre-processing ensures that a signal is always present no matter what the content of the data is. An additional DIGTRX feature is being able to send short messages or callsigns as tone patterns, rather like very low resolution analogue slow scan but the DIGTRX software uses it for station identification. **Figs 20.2 and 20.3** show screen shots from the DIGTRX program.

Fig 20.3: An SSTV image received by DIGTRX

The best place to hear SSTV is around 14.230MHz and for DIGTRX around 14.240MHz. Both modes are easy to identify by their distinctive sounds. SSTV produces a repetitive 'blip' against a background of sweeping tones while DIGTRX makes eerie, shrill sounds.

FAST SCAN TELEVISION

As with slow scan modes, there are analogue and digital versions of fast scan amateur television. At the time of writing this, it is still quite expensive to buy or build digital transmitters but the very low cost of digital receivers is persuading more and more people to try this mode. The digital standards being adopted by amateur stations are very similar to those used by commercial broadcasters and this has resulted in mass manufactured domestic receivers becoming easily obtainable at very reasonable prices. As time goes by and home users 'upgrade' or replace their receivers, they will become disposable items and easy to get hold of for repair or modification.

Analogue and digital fast scan modes can only be used on the 430MHz band and above because of the wide bandwidths they occupy. Indeed, on the 430MHz band itself, only limited quality can be sent, otherwise the edges of the modulation envelope would spread outside the band allocation. Using such a wide portion of band does not necessarily imply that interference will be caused to other users because spreading the power over a wider space means that less lies on any particular frequency. The power distribution changes with picture content and, coupled with the universally adopted horizontal antenna polarisation, the presence of properly engineered television transmissions hardly affects other stations.

On 1.3GHz and above, the bands are sufficiently wide, and FM is also normally used as it makes the transmitting equipment much easier to build. In the transmitter, it is much easier to apply the modulation signal to a varactor (varicap) diode in the oscillator tuning circuit than to control the carrier amplitude linearly. The power amplifying stages are also simplified as they too no longer have to be linear. In fact, most FM television transmitters are run flat out to achieve the best efficiency. Harmonic suppression, if necessary, is achieved in the normal way with LC or cavity filters.

The bands used for fast scan TV run from 430MHz up to the high microwave bands, and with a spread as wide as this, the techniques used to transmit and receive vary widely. The most popular bands are 1.3GHz, 2.3GHz and 10GHz so the detail here is concentrated on equipment suitable for them. These are not the only bands used by any means but they provide a useful starting point for looking at the methods used.

1.3GHz Equipment

This is the most popular ATV band and has wide repeater coverage throughout Europe and beyond. Almost, but not all, transmissions use FM because producing appreciable power from linear devices is quite expensive. FM does not need linear amplifying stages and it is considerably more efficient to run with a con-

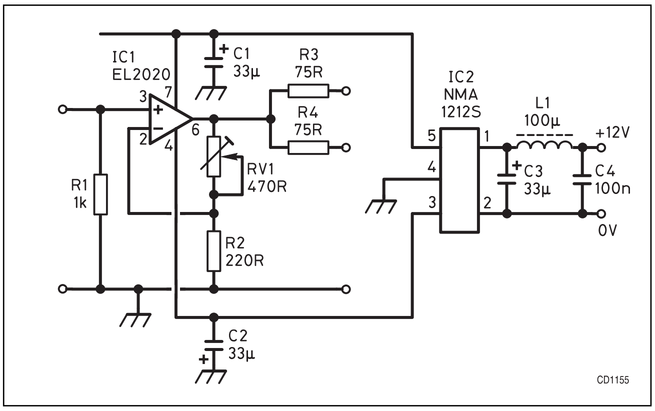

Fig 20.4: Amplifier suitable for raising the video level from a satellite receiver

R1	1K	C1	33µF
R2	220R	C2	33µF
R3	75R	C3	33µF
R4	75R	C4	100nF
RV1	470R	L1	100µH
IC1	EL2020	IC2	NMA1212S

Table 20.1: Parts list for the video amplifier

stant hard-driven PA stage. The popularity comes primarily from the ease of getting hold of suitable equipment. Almost all the domestic satellite receivers used in the world are capable of receiving the whole of the 23cm band and as more users switch to digital satellite television, their old analogue receivers are given away or discarded. With nothing more than adding a suitable antenna, a complete receiving system is ready made.

Although an unmodified satellite receiver can be used, a few simple modifications can dramatically improve their performance for amateur use. To see why the modifications help, it is first necessary to understand how the receivers were intended to work when picking up satellite transmissions. A domestic receiving system has two parts, one mounted at the focal point of the satellite dish, the other somewhere indoors, usually near the home TV. The outdoor part is a dish that is either a parabolic or 'prime focus' reflector but more likely an offset-feed dish which is actually a slanted section of a parabola. A prime focus dish has its receiving antenna on the centre axis of the bowl, equally spaced from the edge of the dish and usually mounted on three support arms. A line extended from the middle of the bowl, through the antenna would head straight toward the satellite signal source.

This type of construction has two disadvantages, firstly the antenna and support arms are casting a shadow on the dish, obstructing some of the signal path and secondly, they are difficult to mount as their centre of gravity is inconveniently under the dish where attaching a pole is difficult. In an offset design, the curve of the bowl is modified so the focal point is no longer directly in front of the dish, this slightly reduces its ability to concentrate as much signal on the antenna but without the shadowing the loss is more than overcome. The weight distribution is also improved, making it possible to attach to a pole behind the dish. Whichever type is used, the intention is to capture and concentrate as much RF as possible on to the antenna. A typical domestic satellite dish will give an effective gain of about 35dBd.

The antenna is connected to what is similar to the front end of a superhet receiver. It firstly connects to several amplifier stages, then to a mixer where a local oscillator at about 9.75GHz is added, then to several IF amplifying stages. A filter between the mixer and first IF stage makes sure that only the RF minus LO product is selected. Satellite signals in the 10 to 12 GHz region are down-converted to around 750 - 1750MHz so they can be fed indoors through conventional co-axial cable. Importantly, this encompasses the 23cm band. Collectively, the electronics at the dish end is called an LNB or 'Low Noise Block converter' and it will amplify by about 60dB. We will revisit the LNB and dish later when we move on to the 10GHz band.

As you will have seen, the indoor satellite receiver box is expecting around 100dB of gain in line with its input socket and consequently isn't designed to be particularly sensitive or have a low noise figure. A DC feed to the LNB is also present on the input socket, this would normally be the supply to dish so a separate cable is not needed. Signal and power are split at the receiver input and the LNB output using an LC network.

An antenna connected directly to the input of the receiver will give good results when the signal strength is fairly high but it is absolutely essential to insert a capacitor in line with the co-axial cable centre conductor. A conventional folded dipole has a continuous conduction path up the centre wire, around the dipole and back down the co-axial braid, this will short out the DC feed and could damage the receiver circuitry. A better option is to utilise the DC feed to power a pre-amplifier stage. This not only overcomes the danger of shorting out the supply, it gives the benefit of increasing the signal sensitivity as well. The power is already present, it may as well be put to good use.

Another drawback to satellite receivers is their wide IF bandwidth. Domestic broadcasts use a relatively high modulation index and consequently occupy a chunk of spectrum about 25MHz wide. On the satellite downlink band this is not a problem, there is plenty of empty band to use but when used for amateur purposes, the bandwidth is far in excess of that needed. A wider than necessary bandwidth causes a decrease in signal to noise ratio and makes the system prone to interference from adjacent frequencies. There is no easy solution to this problem as the bandwidth is normally constrained by a SAW (Surface Acoustic Wave) filter which is not 'tweakable'. In practice, directional antennas and tuned pre-amplifiers go a long way toward keeping unwanted signals out of the bandwith and the problem is not as serious as it may first seem. Amateur broadcasts, being relatively narrow band, do however, result in less recovered video from the detector (frequency discriminator) stages. Domestic receivers expect to recover quite a lot of video voltage from the wide satellite broadcast deviation and when presented with a signal of smaller deviation, may not recover enough signal to be useable. The fix for this is simple though, add an extra video amplifier stage. A design for such an amplifier is shown in **Fig 20.4**; a components list is in **Table 20.1**. The PCB is small enough to fit upright behind the rear panels of most

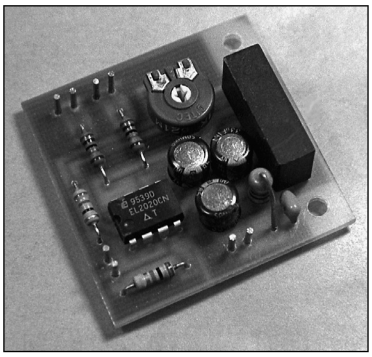

Fig 20.7: The completed video amplifier

receiver boxes (see **Figs 20.5 and 20.6** in the Appendix for PCB and component layouts). **Fig 20.7** is a photograph of the completed amplifier project.

A bonus to using a domestic satellite receiver is that almost all models have an on-screen display of the receiver frequency. In most cases this takes into account that the LNB is downshifting the band by 9.75GHz but to cater for older LNB designs which used 10GHz local oscillators, there is usually an option to select either 9.75 or 10.0GHz offsets. If the latter is chosen, the frequency selected at the input socket on the receiver is exactly 10.0GHz below the frequency indicated so ignoring the first displayed digit gives the effective frequency being received. For example if the receiver indicated 11.296GHz it would actually be tuned to 1296MHz. The same applies to using an LO of 9.75GHz but a little calculation is required to add an extra 250MHz to the frequency shown.

In recent months a new source of receivers has hit the market. These are actually intended to be used with domestic 'video senders', devices that use low RF power to distribute television signals around the home. For example to allow a VCR in one room to be watched in another without running cables between them. They generally come in pairs, one receiver and one transmitter module and unfortunately rarely utilise pre and de-emphasis. This makes them work well together but incompatible with other equipment unless additional filter circuits are added to the input of the transmitter and output of the receiver. They normally use synthesized tuning which gives the option of the user selecting one of four pre-set channels. The synthesizer normally comprises a small microcontroller chip and by careful re-programming, the frequency can be shifted so it works within the permitted amateur bands.

The receiver is generally more sensitive than a satellite box but the additional work needed to ensure compatibility with other equipment can be a problem. The transmitter modules normally only produce a few milliwatts of RF power and will require several stages of amplification to be usable for longer distances. Despite their drawbacks, these modules can make the basis of a very inexpensive television transceiver and they are readily available in ranges covering both the 23cm and 13cm bands.

10GHz Equipment

Despite 10GHz being well into the microwave region, it is remarkably easy to send and receive images on this band. We return to the domestic satellite equipment mentioned earlier but utilise it in a slightly different way. This time, instead of only using the indoor unit, we also use the original dish and LNB. Satellite downlink frequencies are just above the 3cm band and with a little modification it is possible to modify an LNB so it tunes lower than originally intended and sends 3cm signals to an indoor unit instead. Although retuning is quite simple, a screw is turned to move the LO to a lower frequency, there is another obstacle to be overcome. Internally, most LNBs consist of two input stages, one with a horizontal antenna and one with a vertical antenna.

These input stages are selectively powered on and off so only the desired polarisation is picked up. The input stages are combined and fed through several more amplifiers and then through a filter to the mixer. The mixer subtracts the LO, shifting the received frequency down low enough to be carried by co-axial cable to the indoor unit. The filter is the obstacle since it is designed to block stray LO signals from reaching the amplification stages. It is designed to cut off somewhere between the bottom of the satellite broadcast band, around 10.7GHz and the LO frequency of 10GHz or 9.75GHz. That 'somewhere' unfortunately lies perilously close to the 3cm band and depending on manufacturing tolerances, may well block or at least seriously attenuate the signals we want to receive. To use the LNB on 3cm, the filter cut-off frequency needs to be lowered a little. Most filters are fabricated as parallel copper tracks on the PCB and it is not too difficult to extend these by about one millimetre by soldering copper or tin-plate extensions to them. The new filter characteristic is not too important and it is not unknown for the filter to be removed altogether and replaced by a link.

Sometimes, the LO tuning screw may not allow enough adjustment. In these cases it may be necessary to replace the dielectric resonator element (known as “the puck”) with one designed for a lower frequency. As these can be difficult to get hold of in small quantities, it is worthwhile removing the old one and raising it away from the PCB by placing a thin plastic washer underneath it. Mounting it on a pedestal like this will often shift it's frequency enough but be careful to secure it with the minimum amount of glue. A single dot of Cyanoacrylate 'Superglue' will suffice; too much glue may reduce its Q factor enough to stop the oscillator running.

Going back to the dish, offset-feed dishes are very inexpensive and already have suitable mounting arrangement to hold an LNB. They do however, look upwards rather than toward the horizon as would be required for point-to-point communication. If a line is drawn along the axis of the LNB feed horn it will touch the dish close to its centre point but approaching it from an angle well below horizontal. Now imagine a horizontal line drawn across from rim to rim of the dish, immediately in front of its centre, the direction the dish is actually looking is at the same angle as the LNB axis follows but above the second line instead of below it. For example, if the LNB axis approached the centre from 20 degrees below the centre line, it would be focussed on a signal 20 degrees above it. This would be a problem normally as the dish would have to be angled downward to look at the horizon but a simple trick can be used to overcome it: rotating the dish by 90 degrees so its LNB arm is horizontal will change the upward offset to a sideways one. Now the dish simply has to be rotated around its mounting pole so it looks as though it is aiming about 40 degrees off target. The exact angle depends upon the dish design and is best learned by experimentation. It may look strange when the dish is apparently pointing off-course but you get used to it.

Various methods of producing TV signals on 3cm have been tried with great success. Most popular is the modified Gunn Diode module transmitter. These are the units used to detect motion by reporting Doppler shift and are commonly used in automatic door opening units and security alarms. They are actually a simple transceiver, producing an LF output in which the frequency is proportional to the rate of movement nearby. They are simple in operation: a Gunn effect diode is mounted in a cavity tuned to about 10.7GHz. Inside this high-Q tuned circuit, the diode produces a carrier signal. Most of the signal leaves the cavity and exits the unit through a short waveguide, a small amount is picked up by a mixer diode which sits inside that waveguide.

Ordinarily, the diode would produce a small DC voltage by rectifying the carrier signal and indeed this is what it does if there is nothing in front of the waveguide’s exit. If an object reflects any of the signal back, it enters the waveguide and also reaches the mixer diode. The direct carrier and reflected one may or may not be in phase, depending on the distance the waves have travelled to and from the source of the reflection and the mixer out-

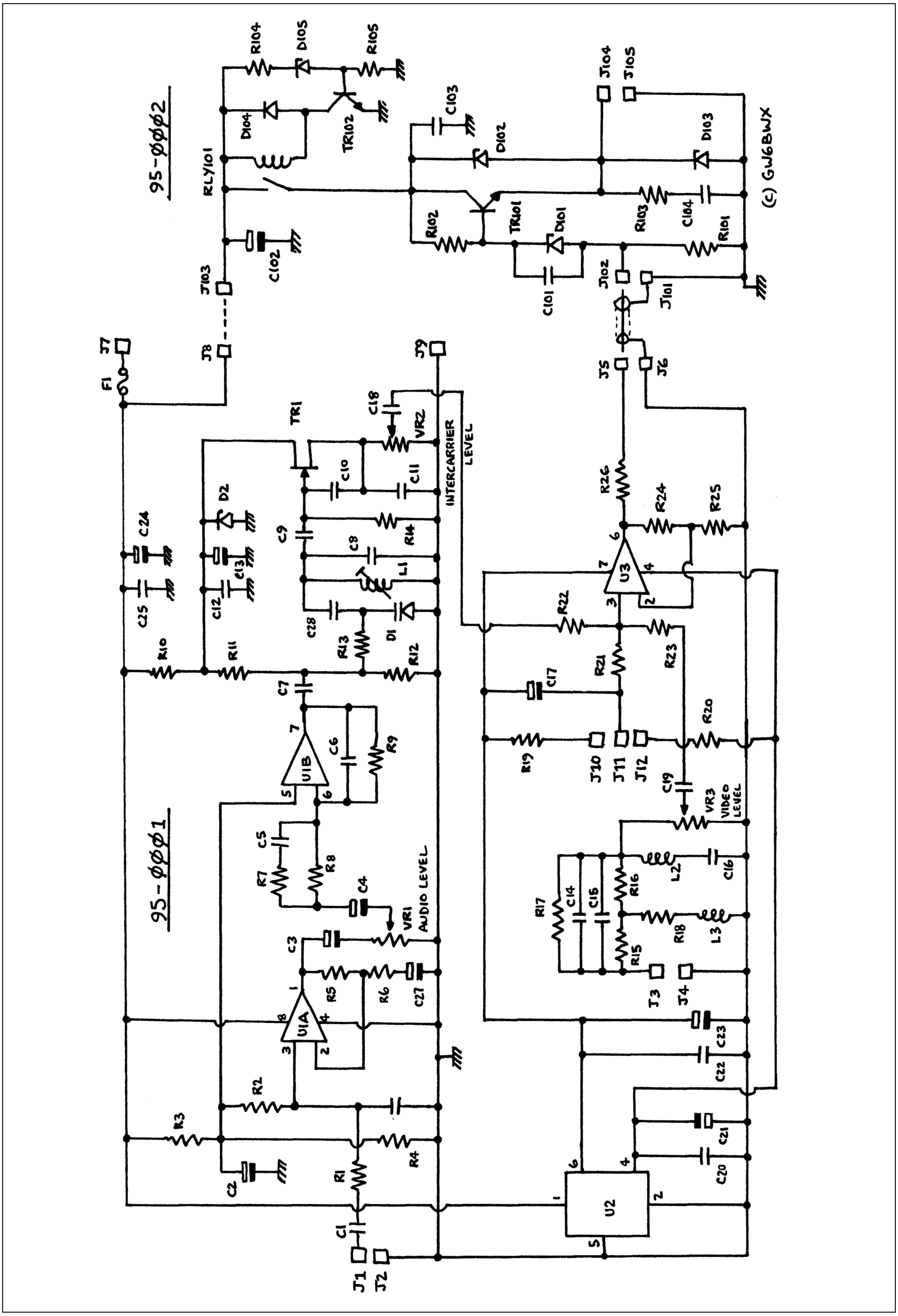

Fig 20.8: Modulator for a 3m Gunn diode. Remote tuning and a sound channel are included

put may vary from close to zero if the waves cancel up to close to twice the voltage if they are in phase and add to each other. Movement in the object causes the phase of the reflected wave to change and an alternating voltage is produced.

For TV purposes we can use another property of Gunn effect modules, that the exact frequency of oscillation is proportional to the voltage applied across the Gunn diode. A word of caution here; these are negative resistance devices, they defy Ohms law, over part of their operating range, the current they draw actually increases as the applied voltage falls. It is very easy to burn them out with excess current by applying insufficient voltage so ensure they are not run with less than about 5V across them and if possible, current limit their power supply as well. Typically they work at about 7-8V and a current of around 100mA. Because the frequency changes with applied voltage, they are very easy to frequency modulate. All you need to do is apply the appropriate DC voltage to set the frequency and superimpose a video signal on it. Usually there is also a mechanical tuning method, a screw penetrating the cavity to slightly alter its volume, this acts like a coarse tuning control while changing the supply works like a fine tuning control.

The simplest TV link is two of these modules, facing each other with the video applied to one module and the mixer on the other, suitably amplified, feeding a monitor. Unfortunately, this arrangement will probably only have a range of a few hundred metres. More commonly, the mixer output is ignored and an LNB is used as the receiver, the range now increases manifoldly. From personal experience, a Gunn module sending video without any other antenna or dish, just the waveguide output alone, has been picked up using a converted LNB and produced perfect colour pictures over a distance of 30km. In fact the signal was so strong that when the module was facing away from my receiver it was still producing good results. A design for a suitable 3cm Gunn modulator unit is shown in **Fig 20.8**, and the components list is in **Fig 20.2**. This not only allows remote tuning of the module so it can be mast mounted, it also adds a 6MHz sound channel to the picture. This can be retuned between 5.5 and 6.5MHz to cater for TV receivers outside the UK. PCB artwork and component layouts for this project can be found at [3].

10GHz transmitters have also been made using multiplier chains, starting with a relatively low frequency and multiplying it up to the desired 3cm output and by utilising dielectric resonators to set an oscillator frequency directly in the band. Most interestingly, several people have managed to reverse the operation of LNBs by starting with the LO and physically reversing part of their PCB so the input amplifiers become output stages. This has the advantage the LNB is already optimally designed to fit in a standard dish and of course, no cost is involved. Typical output power from a reversed LNB is 50mW where a Gunn would only produce about one tenth of that. Options are retuning the LO to the desired frequency and modulating its supply voltage to achieve the FM signal, or utilising the original mixer to up-convert a lower frequency FM signal. The latter method lends itself to using the LNB completely in reverse, feeding a 23cm FM signal in with the DC power and getting 3cm out.

Part / Value	Quantity	Schematic Reference
18R	1	R18
75R	3	R15, 16, 26 (see text)
82R	1	R101 (see text)
300R	1	R17
390R	1	R10
470R	1	R103
1K	5	R23, 24, 25, 102
2K2	3	R6, 7, 22
10K	5	R3, 4, 5, 13, 21
47K	1	R2
68K	1	R8
100K	3	R11, 12, 105
330K	2	R9, 14
1K variable	3	VR1, 2, 3
22p	3	C6, 8, 18
33p	2	C10, 11
68p	1	C16 (if required)
100p	1	C28
680p	2	C15, 16
1n	4	C5, 9, 14, 101
0.1µ (100n)	9	C1, 7, 12, 19, 20, 22, 25, 103,104
2µ2	2	C4,27
10µ	3	C2, 3, 17
47µ	5	C13, 21,23, 24,102
10µH	2	L2, 3 (L2 if required)
15µH	1	L1
6V8	1	D102
8V2	2	D2, 101
9V1	2	D103, 105
1N4148	1	D104
MV1208	1	D1
BF244	1	TR1
BD131	1	TR101
BC337	1	TR102
TL072	1	U1
NMA1212S	1	U2
EL2020	1	U3
Relay	1	RLY1
Veropins	17	J1-12, J101-105

Tuning control either 10 turn or single turn but MUST be 10k value and preferably linear track. This part is not mounted on the PCBs. Use a type that suits your preferred box or enclosure. A heatsink can be fitted to TR101 as it runs quite warm. Fold a 30mm x 15mm aluminium strip at 90 degrees, half way along its length. Then drill a 3mm mounting hole in the centre of one of the 'wings', 5mm from one side.

Table 20.2: Parts list for the 3cm Gunn diode modulator

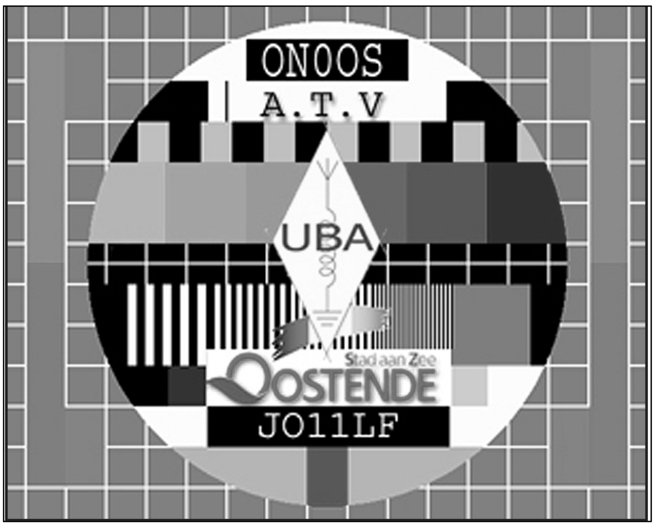

Fig 20.9: An ATV test card

OPERATING PRACTICE

Television is a far more 'friendly' mode of operation, no longer is the other person just a voice, they can now show facial expression. How many times have you passed right by someone you have spoken to on the air without realising who they were? It also allows items to be demonstrated rather than just described; that's very useful, particularly if a talk-back channel is used so the demonstration becomes interactive. When using ATV, the principles are the same as for voice communication. There are 'centre of activity' frequencies, calling frequencies and a wide coverage of repeaters. CQ calls are either made by voice or by transmitting a suitably worded caption as a picture. When live pictures are sent, be careful about their content; remember that the camera can also see what is going on in the background. It is also useful to monitor your own pictures and if you are showing a face shot, place the camera close to the monitor screen, preferably right above it. This makes it look as though you are looking straight at the person receiving the picture while you are actually monitoring your own video. It is considered impolite to be looking away from the camera while talking to someone, just as it would be in close company.

A club, affiliated to the RSGB, exists to support enthusiasts of television and imaging. It is the British Amateur Television Club (BATC), membership is open to anyone around the world. A colour magazine, *CQ-TV*, is distributed to members quarterly and the club can supply some ATV items from its Members Services Department. More details are available from [4].

Full construction details of the equipment mentioned in this chapter, including PCB designs are available at [3] which also carries other video and imaging projects.

REFERENCES

[1] MMSSTV slow scan television software can be downloaded from http://mmhamsoft.ham-radio.ch/mmsstv/index.htm

[2] DIDTRX digital slow scan software can be downloaded from PY4ZBZ's web page at: http://planeta.terra.com.br/lazer/py4zbz/

[4] Construction details of the equipment mentioned in this chapter, including PCB designs. http://www.atv-projects.com.

[3] British Amateur Television Club. http://www.batc.org.uk. Membership Secretary, The Villa, Plas Panteidal, Aberdyfi, LL35 0RF, UK.