satellite television receiver indoor unit

1. introduction

television signals are usually retransmitted by satellites using the 4ghz, 11ghz or 12ghz frequency bands. since conventional transmission lines like coaxial cables have very high losses at microwave frequencies, the first downconverter is usually located rather close to the antenna: usually it is installed directly behind the feed of a parabolic dish antenna. although the resulting intermediate frequency may fall at least partially in the frequency range covered by an ordinary tv-set, the downconverted satellite signal can not be accepted by an ordinary terrestrial television receiver due to the large differences in the signal format. terrestrial television broadcasting in the vhf and uhf bands uses amplitude modulation for the video signal and an additional frequency modulated carrier for the corresponding sound information. on the other hand, satellite television transmissions use wideband frequency modulation for the video signal. the corresponding sound can be transmitted in many different ways: usually a frequency modulated subcarrier (between 5 and 8mhz) is added to the baseband video signal just in front of the main wideband fm modulator, although other systems are being used too, like a digitally modulated subcarrier or a digital sound-in-sync or as a separate carrier transmitted through a separate satellite transponder.

a separate if amplifier and fm demodulator is therefore required for satellite tv transmissions. since most existing tv sets only accept vhf or uhf modulated signals, an am modulator is usually connected to the output of the fm demodulator. a suitable circuit to demodulate the sound information should also be included since the sound subcarrier frequency usually differs from the standard 5.5mhz. all the above circuits are installed together with a power supply for the outdoor microwave front-end in a suitable case and are usually referred as the 'indoor unit'. since the outdoor microwave downconverter is usually fixed-tuned (block downconverter), the indoor unit should be tunable across the intermediate frequency band supplied by the outdoor equipment. therefore the indoor unit usually includes a second, tunable downconverter to a second, fixed tuned if chain.

the first if band generally ranges from about 900mhz to 1700mhz (+-100mhz). this frequency choice is simply imposed by the available cables and semiconductors and the need to avoid interferences from powerful terrestrial uhf broadcast stations. note that the instantaneous first if bandwidth may be as wide as 800mhz, depending on the actual satellite band being received. the second if is fixed tuned and its bandwidth should correspond to the modulation bandwidth of the received signal, which ranges from 25mhz to 36mhz. several second if values are actually being used: older equipment uses 70mhz or 134mhz (center frequencies) while recent if chains use 400mhz, 480mhz or 612mhz due to the ease of filtering out the second conversion image frequency. the indoor unit described in this article uses a second if of 200mhz, which was chosen as a compromise between the availability of suitable components and circuit complexity.the first if band ranges from 850mhz to 1600mhz with a considerable overlap at both band edges to match the ku-band low-noise downconverter described earlier and is also compatible with commercially available block downconverters.

2. treshold extension demodulators

actual satellites can only carry weak transmitters that are up to 40000km away from the receiving earth stations. frequency modulation is being used for the transmission of television signals over satellite transponders since it offers the best performance for a given satellite transmitter output power in comparison with other modulation types: first, the satellite transmitter can operate close to saturation with a high efficiency, second, in the demodulation process, the signal to noise ratio can be increased considerably by a fixed amount known as the fm advantage. considering the deviation and the preemphasis of satellite tv transmissions the fm advantage amounts up to 30db. of course, this improvement in the signal to noise ratio can only be obtained if the signal to noise ratio at the input of the fm demodulator is above a certain value known as the treshold of a fm demodulator. for a conventional fm demodulator including an efficient limiter and a discriminator the treshold occurs around 10db to 12db signal to noise ratio at the input. above treshold such a demodulator provides a virtually noise free picture, while below treshold the output is not useable.

at the output of any fm demodulator the noise appears in two different forms: as a 'fine-grain' noise and as a 'rough' noise. the 'fine-grain' noise is almost independent of the demodulator treshold. well above the demodulator treshold it is the only form of noise present. on a tv picture this kind of noise causes the familiar 'snow' effect, although much less disturbing than in the case of a conventional am transmission. decreasing the signal to noise ratio at the input of the fm demodulator the 'rough' noise starts appearing as random spikes in the signal. the amplitude of these spikes is comparable to the full signal deviation while their duration is determined by the deemphasis network. decreasing further the input signal to noise ratio the frequency of these spikes rapidly increases corrupting the useful signal. in the case of television signals the 'rough' noise appears as random short black and white lines on the picture popularly called 'sparklies'.

since the available rf signal to noise ratio is limited by the satellite tx power and antenna, receiving antenna size and receiver noise figure, improving the demodulator performance by decreasing its treshold is well worth the effort. such improved demodulators are usually called treshold extension demodulators. the operation of any treshold extension demodulator is based on the fact that the instantaneous spectrum width of a frequency modulated signal is usually smaller than the whole occupied bandwidth. this is especially true when the spectrum of the modulating signal only contains significant very low frequency components. a tracking filter can be built so that the noise bandwidth is reduced in front of the demodulator increasing the effective signal to noise ratio at the input of the demodulator above its treshold. treshold extension demodulators allow the reception of very weak signals even when the carrier to noise ratio is below 0db. unfortunately treshold extension demodulators also have a major disadvantage: the tracking filter has difficulties in following fast and wide deviations, noise induced sparklies will therefore appear at well defined places in the picture, usually after sharp black/white or white/black transitions. this unwanted side effect is actually proportional to the amount of treshold extension.

treshold extension demodulators can be built as either phase-locked-loops or varicap-tuned tracking filter/ discriminator combinations. pll demodulators are widely used since they are easy to build and align and the treshold is easily adjustable. on the other hand, the tracking filter/ discriminator demodulators provide a slightly better performance but they are more complex and instable although single-chip demodulators according to this principle will probably make them more popular (plessey sl1453). in any case, a treshold extension demodulator requires a linear, non limiting if chain with an accurate agc and a careful design and construction of the demodulator itself, otherwise the results may be even worse than without treshold extension.

3. block diagram of the indoor unit

the block diagram of the satellite television receiver indoor unit is shown on fig. 1 and includes the following modules: a second tunable downconverter, an agc attenuator, a second if amplifier and agc detector, a phase-locked-loop demodulator, an am video modulator, a sound demodulator and a regulated dc voltage converter. the indoor unit shown on fig. 1 accepts the broadband if output of the outdoor antena mounted block downconverter and supplies the latter with +12vdc through the same coaxial cable. after processing the signal the circuit provides three separate outputs: a baseband video output to feed a tv-monitor, a modulated vhf band 1 signal to feed a conventional tv receiver without a baseband video input and an audio output to drive a loudspeaker. the indoor unit shown does not include descramblers to decode scrambled tv transmissions and the sound demodulator is only suitable for conventional frequency modulated audio subcarriers. if required these circuits can be added later, but most satellite tv signals over europe have a clear (unscrambled) video and one or more fm audio subcarriers.

the receiver requires a single supply voltage of +12vdc (negative grounded) and can be battery supplied. of course it is possible to add a mains transformer, rectifier and a suitable voltage regulator (7812) for mains operation. the regulated dc voltage converter generates from the available +12vdc a stabilized voltage of about +25vdc supplying two front panel controls: the channel frequency tuning potentiometer and the audio subcarrier frequency potentiometer, both feeding the corresponding varicap diodes. all the other circuits only require a +12vdc supply voltage.

the receiver selectivity is given by the tuned circuits in the second tunable downconverter and second if amplifier. since the only source of interference is thermal noise, the requirements are not very high. in fact, the pll treshold extension demodulator itself determines the bandwidth of the receiver. on the other hand a pll treshold extension demodulator requires a very stable input signal level since the demodulator transfer function and in particular its bandwidth is directly proportional to the input signal level. the signal level can be adjusted by the corresponding potentiometer 'agc level'. when adjusting the antenna and/or the receiver it may be useful to switch off the agc function. in this case the 'agc level' potentiometer acts as a manual gain control.
an automatic frequency control circuit is not included since the stability of both downconverters is sufficient. in any case, the modulating video signal contains a considerable dc component and a conventional average value afc circuit would detune the receiver with very bright or very dark pictures.
a keyed afc should be used that uses as a reference the sync level or the retrace black level.

all satellite tv transmissions include a spectrum dispersion waveform. this is necessary to avoid the concentration of all the transmitter power into a few narrow spectrum lines, especially when transmitting stationary pictures like test patterns, and limit the interferences to terrestrial services operating in the same frequency bands. the spectrum dispersion waveform is usually a triangular wave of half the field frequency, the edges of the triangular wave being synchronised with the vertical retrace period to reduce the interference to the tv picture. such a spectrum dispersion waveform can easily be removed from the video signal by a simple video clamping circuit. this circuit is usually already present in good quality tv monitors, however a video clamping stage is required in front of the vhf am modulator. since satellite signals have different deviations and preemphasis, the video signal level should be adjusted in front of the modulator. the differences between different preemphasis are small and a simple integrator, included in the pll demodulator module, gives good results for all the available satellite tv signals.

the sound demodulator is very similar to those being used in conventional tv-sets except that all the circuits are tunable using varicap diodes to match the actual audio subcarrier frequency. the input of the audio amplifier can also be switched directly to the output of the pll demodulator to listen to the video signal. this is very useful when searching for a satellite by adjusting the antenna direction and receiver frequency. the well known field frequency hum can be heard at signal to noise ratios as low as -20db, much before anything can be seen on the tv screen.

4. second tunable downconverter

the second tunable downconverter (see fig. 2) includes a two stage tunable band pass filter with varicap diodes for image rejection, a buffer rf amplifier stage to overcome the losses in the filter and provide the mixer with a stable output impedance, a broadband voltage controlled oscillator and a common base bipolar transistor mixer stage.

although the block diagram is not much different from a standard uhf tv-tuner, the actual design and practical construction is much more demanding, since components with comparable electrical performances are not readily available for higher frequencies. for example, the q-factor of a readily available uhf varicap diode is only between 10 and 20 at 1.5ghz depending on the bias voltage. broadband tunable high-q filters can obviously not be built with such diodes. almost all suitable diodes, like bb221 or bb505, have a minimum capacity of about 2pf. the inductivity required to resonate such a diode in the 1 to 2ghz range is very small and a printed circuit board made of conventional 1.6mm thick glassfiber-epoxy can not be used. the performance of the diode is further limited by the diode package parasitic inductivity. practical experiments have shown that glass packaged diodes (do-35), like bb221 or bb505, have a lower parasitic inductivity than earlier plastic packaged types like bb105.

the input bandpass filter consists of two resonant circuits made of the two bb505b varicap diodes and inductors l3 and l5 (short air dielectric microstrips). the coupling between the two resonant circuits and to the rest of the circuit is inductive (l2, l4 and l6), since it offers a more constant filter performance across a wide frequency band than capacitive coupling and is easy to implement in practice too. l1 is not a part of the filter, it is just a lambda/4 choke to feed the +12v supply voltage to the outdoor unit through the coaxial cable. the insertion loss of the filter is about 4db per resonant circuit so that the amplifier stage with t1 (bfq69) is just sufficient to recover the overall filter insertion loss. the most important function of t1 is however to provide the mixer and the vco with a stable output impedance to prevent frequency jumps and other instabilities of the vco.

the vco operates 200mhz above the input frequency for two reasons: first, the required relative frequency coverage of the vco is smaller and the tracking between the vco and the input tuned filter is easier to acheive, second, due to the parasitic inductivity of the varicap diodes in the input filter, their self series resonance falls almost exactly on the image frequency in a wide frequency range yielding a 40db overall image rejection in the band center in spite of the poor diode q-factor. this is really a rare occasion that the parasitic inductivity of a component turns out so useful...

of course it is not easy to build a broadband oscillator with poor performance varicap diodes. generally, an oscillator consists of a phase shifting network that determines the oscillation frequency and an amplifier to compensate the losses in the phase shifting network and supply some power to an external useful load. in the real world, the amplifier has its own phase shift which is also frequency dependent, normally just in the opposite direction of that required to build a broadband vco. therefore the phase shifting network must also compensate the phase shift of the amplifier and this limits the frequency range covered. from the above it is evident that it is not possible to build a broadband vco with a single poor performance tuning element, like either one or more varicap diodes connected as a single variable capacitor. the solution is to split the required phase shift between two or more phase shifting elements.

the vco shown here uses three varicap diodes connected in a phase shifting network between the collector and base of the oscillator transistor t2 (bfq69), operating as a common emitter amplifier. l11 is a lambda/4 choke feeding the tuning voltage, only l7 has a role in determining the oscillator frequency. the output is taken through an inductive link (l8). note that the varicap diode connected to the base receives a slightly lower bias voltage than the remaining diodes. this is certainly not ideal, but the bias network required to supply all the diodes with the same voltage would introduce very high parasitics.
a wideband oscilator transistor requires an accurate bias network to obtain the best possible performance. t3 (bc308) stabilizes the operating current through the oscillator transistor t2. the led diode is a very good 'zener' diode for about 2v, in comparison with a real zener diode it has a lower dynamic resistance, its temperature coefficient subtracts precisely from the t3 b-e junction tc and most important of all, it does not produce noise. as every feedback circuit the bias network requires a frequency compensation to avoid instabilities and this is provided by the 1nf capacitor between the collector of t3 and ground.

the vco shown can (depending on component tolerances and construction) usually cover the freqency range from 800mhz up to 2000mhz in a single tuning voltage sweep from 0v to 35v. this would allow a theoretical converter input frequency range from 600mhz up to 1800mhz. of course it is impossible to obtain a good tracking with the input filter across the whole mentioned frequency band. practically the 800 to 1700mhz band can be covered with relatively little gain variation. with the outdoor unit described earlier, the gain variation across the 850 to 1600mhz frequency range supplied by the outdoor unit is in the 10 to 15db range with a maximum in the band center and a sharp drop-off at the band edges. this gain variation is however mainly caused by the three stage first if amplifier of the outdoor unit.

the mixer employs a single transistor t4 (bfq69) in common base configuration. both the input and oscillator signals are fed to the emitter. l8, l9 and the 1nf capacitor represent a a high impedance for the input frequency and at the same time a low impedance return path for the 200mhz second intermediate frequency. the nominally 270ohm resistor from l9 to ground is used to suppres a parasitic resonance that may cause spurious oscillations of t4. the pi-filter at the mixer output transforms the high t4 collector output impedance down to about 50ohm and filters out the rests of the local oscillator signal. due to the wide relative bandwidth of the signal at 200mhz, the output circuit has to be dampened by the 1.5kohm resistor.

other types of mixers were tested too with satisfactory results, in particular a single-ended common emitter bfq69 mixer and a balanced schottky diode mixer. the common base mixer has less gain variation across the frequency band than the common emitter mixer and is much easier to build and cheaper than the schottky diode mixer.

5. agc attenuator

the agc attenuator module (see fig. 3) includes an agc amplifier, a pin diode driver stage and an electronic pi attenuator with three pin diodes. the agc amplifier ic1 (741) is an operational amplifier connected to compare the agc voltage incoming from the agc detector with the voltage preset with the 'agc level' potentiometer. the gain of the amplifier is limited to about 150 with a resistor network. the 330n capacitor connected between the input and the output of the op-amp determines the agc time constant. the latter is not critical since the receiver processes a frequency modulated, constant amplitude signal. it is only necessary to ensure that the agc feedback loop is stable. when the agc on/off switch is open, ic1 works as a voltage follower and the 'agc level' potentiometer allows a manual gain control.

the pin diode attenuator follows the standard design used in some tv tuners. the pin diode driver stage supplies the pin diodes with appropriate currents so that both the input and the output impedances of the attenuator are close to 50ohm regardless of the actual control voltage. decoupling capacitors are included at both input and output. l1 is only a choke for 200mhz.

6. second if amplifier and agc detector

the second if amplifier and agc detector module (see fig. 4) includes three almost identical broadband amplifier stages at 200mhz, an agc detector ic1 and corresponding amplifier ic2. bfr90 (or bfr34a or similar) bipolar microwave transistors are used in all the three amplifier stages since mosfets can not give sufficient bandwidth and useable gain at the same time. of course, bipolar transistors also have some disadvantages: they have an extremly high gain at low frequencies and they still have some gain at frequencies much above 200mhz. to avoid oscillations and overload problems at low frequencies (below 50mhz) an 1kohm/1nf feedback network is added to each transistor. the coupling between the amplifier stages is made with series resonant circuits to further limit the gain at very high and very low frequencies and provide some selectivity. finally, the high frequency gain is limited by the small capacitors connected between the base of each transistor and ground. incidentally these capacitors improve the matching and bandwidth at 200mhz. although the gain of the transistors is small above 1000mhz, this frequency range should be rejected to avoid saturating the amplifier with the second local oscillator signal.

the output of the amplifier is fed through a small capacitor to the pll demodulator since the signal level required by the latter is smaller than that required by the agc detector. the agc detector ic1 (s042p) is a multiplier/squarer circuit. since a signal multiplied by itself gives also a dc component proportional to the signal power, a squarer circuit is an ideal power detector. the main advantages over conventional diode detectors are that a squarer ic is able to reliably detect rf voltages of only a few millivolts and due to its symmetrical monolithic construction it does not suffer from thermal instability problems. the output of ic1 is available as a voltage difference between the two output pins. an operational amplifier (ic2 741) transforms this voltage difference into an agc voltage referred to ground. the zero signal level can be adjusted with the 10kohm trimmer. the polarity of the signal is selected so that the output voltage increases when the rf signal level increases.

the output of ic2 (741) can not reach ground since it operates with a single positive power supply. this does not disturb the operation of the agc attenuator module, however the level indicator (s-meter) negative contact should be connected to a resistive divider instead of being grounded.

7. phase-locked-loop demodulator

the pll demodulator module (see fig.5) includes a pll circuit with a current controlled oscillator, a phase detector and a loop amplifier and a video amplifier including the deemphasis network. the pll loop must be fast enough to track the wide and fast deviation of the preemphasised video signal frequency modulated carrier. phase-locked-loops are not very stable feedback loops. the reason is very simple: a phase detector controls the frequency of an oscillator introducing a 90degree theoretical phase shift. the delay of all other components has to be kept below 90degrees to keep the total phase shift below 180degrees and the feedback loop stable. all the components of a video demodulator phase locked loop should therefore not just be able to operate at video frequencies but also to introduce a minimum phase delay up to a few mhz. a monolithic integrated circuit including all the components of a pll is certainly the best solution. unfortunately suitable integrated circuits are not yet easily available and are certainly not cheap. cheap pll ics like the ne560, ne561 or ne564 can only operate up to 60-80mhz and their performance as wideband video demodulators is marginal at best. a pll circuit built from discrete components was finally chosen: at least the performances of the various stages could be tailored as required.

the phase detector of a treshold extension pll demodulator must operate in a linear input signal mode. the input signal level directly influences the phase detector gain and as a consequence the loop gain and the demodulator bandwidth. adjusting the input signal level with the 'agc level' control the width of the demodulator and the actual amount of treshold extension can be adjusted. unlike conventional discriminators a treshold extension pll demodulator is not affected by out of band signals or noise as long as these do not overdrive the phase detector out of its linear range. since all the signals in the satellite bands are of the same order of magnitude, only a rough selectivity is required in front of the treshold extension pll demodulator to avoid overload problems while the demodulator itself determines the receiver bandwidth and selectivity. a side advantage of a pll demodulator is that a complex and/or expensive if filter can be avoided.

the phase detector is a balanced mixer integrated circuit ic1 (s042p), which has two symmetrical high impedance outputs. a loop filter network is connected between these outputs to compensate the phase response and improve the loop stability. a symmetry trimmer is added to compensate the tolerances of both the phase detector and the subsequent loop amplifier. t1 and t2 (both 2n2369) are emitter followers to decrease the phase detector output impedance feeding the differential loop amplifier and the output video amplifier. a differential circuit is required for the loop amplifier (t3 and t4) since it has an excellent dc stability. the differential stage is supplied by a constant current source (t5). the output of the differential stage is a current to control the oscillator. another constant current source (t6) supplies a bias current to the oscillator.

a current controlled oscillator is used in place of a more common voltage controlled oscillator since its frequency can be controlled much faster than the voltage across a varicap diode. the current controlled oscillator is a blocking oscillator built with two rf transistors t7 and t8 (both bfr90 or bfr34a or similar) acting as a negative resistance and a center tap coil (l1). the frequency of such an oscillator, neglecting the parassitic effects, is exactly inversely proportional to the dc current flowing through the circuit. since the dyinamic impedance of the circuit is small, it is almost an ideal load for the differential loop amplifier and the phase delay introduced by the loop amplifier is very small. the output signal is taken with a link to l1 to feed ic1, the phase detector.

part of the phase detector output signal is ac coupled to the input of the video amplifier ic2 (733). just in front of the video amplifier a simple deemphasis network is inserted consisting of a simple rc lowpass cell. the latter was found suitable for all available satellite tv transmissions, in any case this part of the circuit is not critical at all. after deemphasis the video signal level is very low and a high gain (34db) video amplifier is required to obtain a standard video signal level in the 1vpp range. the video amplifier ic2 has two outputs of both polarities. these are fed to a video polarity selector switch. the video polarity of a fm signal may result inverted after a downconversion, if the local oscillator operates above the input signal frequency. since outdoor units for the 11ghz band usually have a local oscillator around 10ghz while the 4ghz band outdoor units have a local oscillator around 5ghz, the demodulated signal from the latter will have its polarity inverted when compared with that obtained from the former. finally, some stations already transmit with the polarity inverted.

8. am video modulator
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the am video modulator module (see fig. 6) includes a video clamping stage, a vhf am modulator and two emitter followers for impedance matching. after the first emitter follower stage (t1 bc308) the video signal is capacitively coupled to the emitter of the clamping transistor t2 (2n2369). since the video signal level is much larger than the t2 b-e junction 'knee', t2 conducts only during the most negative tips of the video signal. the time constant of the circuit set by the 100nf coupling capacitor and the 100kohm resistor to ground is set so that t2 conducts on each horizontal sync pulse, each time resetting the dc level of the video signal applied to the base of t3 (bc238). in this way the video clamping stage restores the dc level of the video signal and rejects all low frequency disturbs like the spectrum dispersion waveform. the actual base dc level can be adjusted roughly with the 10kohm trimmer, a fine adjustment can be made with the front panel modulation level control potentiometer.

the modulation level control is necessary since not all satellite tv transmission have the same deviation. an undermodulated tv picture looks rather dark on the tv receiver, but it does not show other defects. an overmodulated tv picture shows defects first on the brightest parts: saturated white and inverted colours in the case of the pal colour system. another s042p (ic1) is used as a self oscillating vhf band 1 am modulator. the output frequency can be adjusted with l1 between about 45mhz and 65mhz (vhf channels 2, 3 and 4). of course a free channel should be selected. note however that the output of ic1 is rich of harmonics so that it should be well filtered if it is to be combined with other terrestrial broadcast channels in a common antenna installation. in any case, the generated vhf am signal only contains the original audio subcarrier, which is normally different from the 5.5mhz terrestrial television standard.

9. sound demodulator

although many different systems are being used for the transmission of the corresponding sound information, the analogue frequency modulated subcarrier system is the most popular. satellite tv signals have different sound subcarrier frequencies, however 6.6mhz or 6.65mhz are generally used for the main audio channel. up to four additional audio subcarriers may be present carrying stereo audio, sound comment in other languages, independent radio-broadcast sound channels and/or test signals. sound subcarriers also have widely different preemphasis and deviation and some also have the dynamic range companded. finally, some telecom 1a and telecom 1b spacecraft transponders are being used exclusively for radio broadcast: the 12.6ghz carrier is only modulated with the spectrum dispersion waveform and four audio subcarriers carrying two stereo radio broadcast pairs.

the sound demodulator module (see fig. 7) is suitable for conventional analogue sound fm subcarriers. it includes an if amplifier, a discriminator and an audio amplifier. all the active components are included in a single integrated circuit tda1190z, which is a complete sound demodulator for tv receivers. the main difference from the circuit for a conventional tv receiver is that the input filter and the discriminator tuned circuit are tunable from about 5mhz up to 8mhz with varicap diodes instead of being fixed tuned to 5.5mhz. the input filter including l1, l2 and the two varicap diodes is designed for narrow deviation signals and may cause a slight distortion of some widely modulated subcarriers. the coupling between the two resonant circuits is through the 2.2nf capacitor connected from the bb204 twin varicap diode common cathode lead to ground. the discriminator circuit (l3) is tuned with another bb204 with the two halves connected in parallel.

the tda1190z is not designed to have a low level discriminator output nor a separate audio amplifier input, it only has an input (pin 6) for a dc volume control. the volume is at maximum when the dc volume control potentimeter is at minimum. if the volume control pin is left open, the volume is practically cut off. fortunately the audio amplifier section of the tda1190z is still operating in this condition and pin 12 can be used as an audio input, for example to monitor the video signal when adjusting the antenna and/or receiver. to select the desired signal, audio or video, a 2x2 switch is required as shown on fig. 7. this detail is intentionally simplified on the block diagram on fig. 1.

10. regulated dc voltage converter

a practical solution to obtain the supply voltage for the varicap diodes is to use a simple regulated voltage converter as shown on fig. 8. t1 (bc213) and t2 (2n1711) form a blocking oscillator. the energy stored in the 470uh choke during the conducting phase of t2 is released as high voltage spikes which are rectified by the 1n4148 diode to charge the 22uf capacitor. when the voltage across this capacitor reaches a determined value, the 10v zener diode connected to the resistive divider starts conducting and turns on the regulating transistor t3 (bc238). the latter proportionally dampens the oscillations to stabilize the output voltage.

in spite of the simple circuit the efficiency is good. the output voltage stability mainly depends on the zener diode used. of course both the input and the output of the converter must be well filtered to avoid disturbing other circuits of the indoor unit. of course the two tuning potentiometers shown on fig. 8 only represent the simpliest solution. a tv tuner potentiometer keyboard can replace the channel tuning potentiometer. a switch to expand the range of the sound tuning potentiometer around 6.6mhz is also very comfortable. finally, one of the tv remote control ic sets could be used to control both the channel tuning voltage and the sound tuning voltage.

11. construction of the second tunable downconverter

the second tunable downconverter can not be built on a printed circuit board and its construction requires a lot of care to match the results of the prototypes. the components should be installed 'in air' as shown on fig. 9 using a tinned unetched piece of pcb laminate of about 50x120mm as a support and as a ground plane for the circuit. all the 470pf capacitors are leadless ceramic discs of 5mm diameter soldered to the ground plane and used also as supports. the 5.6pf capacitor (collector of t4) is a trapezoidal ceramic chip. all the other low value capacitors are ceramic discs of 5mm diameter or smaller with 0.4mm diameter wire leads. the resistors are all 1/8w miniature types. there are also a few supports made of small rectangles of double sided 1.6mm thick glassfiber-epoxy pcb laminate to improve the mechanical stability of the circuit.

l1 and l11 are lambda/4 chokes made of about 6cm of 0.15mm thick cul wire wound on a 1mm internal diameter forming a self supporting coil of 12-14 turns. l3, l5 and l7 are made of 3mm wide strips of 0.1mm thick copper foil. the length of l3 and l5 is 7mm and they are kept 1.5mm above the ground surface. the strips to build l3 and l5 are first cut to about 11mm. then each strip is bent twice and the remaining 2.5mm are used to solder the cold end to ground. l7 is supported by the varicap diodes and the 33pf ceramic disc capacitor about 2mm above the ground plane. the effective length of l7 is the distance between the two bb505b varicap diodes connected to ground. this should be 7mm and the length of the strip required to build l7 is about 8mm. l8 should run parallel to l7 for at least 5mm at a distance of 0.5mm. both l8 and l9 are built from one of the leads of the 1nf capacitor and are kept about 2mm above the ground surface, their complessive length is about 17mm. l2 and l6 are also built from the corresponding capacitor leads and are 10mm long and kept 2mm above the ground plane. l4 is a loop of 4mm internal diameter made of 0.4mm diameter wire plus the connecting leads to couple l3 and l5, which are spaced by 15mm. finally, l10 has 4 self supporting turns of 0.7mm diameter cul wire with a 5mm internal diameter.

all the critical frequency determining components should be installed exactly as shown on fig. 9 with the shortest possible leads. in practice the leads of the transistors and varicap diodes are first shortened to 1.5-2mm and well tinned. note that not all the bfq69 transistors are oriented in the same way. a power supply jumper is omitted for clarity, it is only marked with the two arrows with the letter a on the drawing. the circuit does not require any additional shielding. in any case the components must be accessible for the alignment.

12. construction of the remaining modules

all the remaining modules are built on single sided printed circuit boards. the masters are shown on figures 10, 11, 12, 13, 14 and 15 and the corresponding component location plans on figures 16, 17, 18, 19, 20 and 21. all the components are installed in the conventional way except the ba379 pin diodes and the bfr90 transistors. the ba379 diodes are installed below the printed circuit board into 4mm diameter holes drilled at the marked positions. the bfr90 transistors are installed in a similar way into 6mm diameter holes. the two current controlled oscillator transistors are both installed in a single hole. the two flat transistors are first soldered together one over another and then the combination is put in place on the printed circuit board.

l1 from the agc attenuator and l1 and l2 from the second if amplifier are self supporting coils of 5 turns of 0.7mm cul wire wound on a 5mm internal diameter each. the complex tapped coil of the current controlled oscillator is etched on the printed circuit board and only requires a few jumpers of 0.4mm diameter wire (ex components leads). l1 from the am video modulator should have about 0.7uh, in practice 9 turns of 0.15mm dia cul wire on a 4mm dia support with core and ferrite cap used for tv if transformers. the coils of the sound demodulator are wound on 10.7mhz if transformer supports. l1 and l2 have 28 turns each of 0.1mm dia cul wire and links of 6 turns each of the same wire. l3 only has a winding of 20 turns of the same wire. the inductivity of the resonant windings of l1 and l2 should be 18uh and l3 should have a nominal inductivity of 9uh.

the completed printed circuit boards should be installed in a metal case about 7-9mm above a metal ground plane. no additional shields are required if the pll demodulator and vhf am video modulator modules are sufficiently spaced (10-15cm) from the low level input modules (second tunable downconverter, agc attenuator and second if amplifier), for example installing in the free space in between some 'neutral' modules, like the sound demodulator or the dc voltage converter. a mains transformer will also not disturb the circuit if it is at least a few cm away from the printed circuit boards.

13. alignment of the satellite tv receiver indoor unit

the most critical part of the second tunable downconverter is the broadband vco. as first, the dc operating current of the vco transistor t2 should be checked and corrected if required acting on the 47-56ohm resistor in the emitter of t3. if the collector current of t2 is below 18-22ma there is danger of instable oscillations and a discontinuous tuning curve. on the other hand, if the current is too high, the maximum frequency can not be reached. the operation of the vco across the whole band should now be checked. the maximum frequency (tuning voltage 35v) should be around 2ghz. this can be adjusted by acting on the distance of l7 from the ground plane. if the vco stops oscillating at low tuning voltages, the distance between l7 and the ground plane is too small and as a consequence the inductivity of l7 is too small for proper vco operation. another possible cause is an improper installation of the varicap diodes or other components, especially if their leads are left too long. practically it is sufficient that the oscillator operates reliably down to a tuning voltage of 2-3v. the vco should now be slowly tuned across the whole frequency band checking the output for instable oscillations and/or frequency jumps. if a spectrum analyzer is not available, the voltage on the collector of t3 is a good indication of the status of the oscillator. a conventional low frequency (10mhz) oscilloscope is sufficient to detect parasitic oscillations or sudden voltage jumps. the t3 collector voltage must vary smoothly with the tuning voltage if the vco is oscillating properly. the vco output level can now be estimated checking the dc voltage on the emitter of t4 (through a rf choke). this is around 1.5v without any vco signal. applying the signal it should increase by a few hundred mv in the band center and less at band edges. the input tunable filter usually does not require any adjustment. in any case, the tracking with the vco can easily be checked later, when all the receiver modules are operating.

the operation of the agc attenuator module and the second if amplifier and agc detector module can be checked using a noise generator as a signal source. the zero signal level agc voltage should be adjusted with the corresponding trimmer to 2.5-3.5v. resistors r1 and r2 should be selected so that the full scale deflection of the level indicator corresponds to about 6v difference of the agc voltage. l1 and l2 in the second if amplifier are tuned by adjusting the spacing of the turns to make the gain maximum coincide with the desired band center. this is also valid for l10 at the output of the second tunable downconverter. these adjustments are not critical at all and if suitable test equipment is not available, the turns of the mentioned coils can simply be spaced to about 6-8mm total coil length.

the phase locked loop module should also be first checked alone. the current controlled oscillator frequency should be 200mhz +-15mhz and should be adjustable for at least +-30mhz with the 10kohm symmetry trimmer. since the frequency depends on the bias current, it also depends on the led used in the constant current sources. in the prototypes red leds producing a voltage fall of about 2v were used. note that some older red leds only produce a voltage fall of about 1.6v since they are based on a different semiconductor while yellow and green leds have an even higher voltage fall. the pll demodulator is also sensitive on the input termination impedance and in some cases it may lock on its own oscillator signal. to avoid this problem it is recommended that the cable to the second if amplifier is 20-25cm long. a resistor across the output of the second if amplifier (r3 on fig. 4) of about 150ohm will also help solving this problem. finally, the symmetry trimmer has to be adjusted to prevent this problem (usually close to the center).

the various modules of the indoor unit can now be installed in a suitable case, connected together and checked on a live satellite signal incoming from an operating outdoor unit. to search for a satellite signal the audio amplifier has to be connected directly to the output of the pll demodulator. when the characteristic frame frequency hum is heard, a tv monitor can be connected. only when a reasonable quality stable image is obtained on the tv monitor adjusting both the channel frequency and the signal level the alignment of the vhf am video modulator can be performed. finally, the sound tuning voltage is adjusted between 5 and 10v to detect the (main) sound subcarrier. then l1 and l2 are adjusted for the best signal to noise ratio and minimum distortion and l3 is adjusted for the maximum undistorted audio output. of course it is assumed that the selected satellite transmission is an ordinary pal (or secam or ntsc) transmission and that it has a fm sound subcarrier.

14. conclusion

the satellite tv receiver indoor unit described is designed for amateur purposes operating in 'amateur' conditions with relatively small antennas and poor signal to noise ratios. when a strong signal with a good signal to noise ratio is available, a conventional demodulator without treshold extension will probably provide better results. the sound demodulator is also designed for poor signal to noise ratios sacrifying the audio quality. the if band used, 200mhz, is not very standard, however the second tunable downconverter can easily be modified for 480mhz replacing the vco transistor t2 with a better microwave type (bfq74) to reach higher frequencies. in this way standard 480mhz if components can be used. a converter for the audio subcarrier could also be added to feed a standard 5.5mhz subcarrier to the tv receiver.

the satellite tv receiver indoor unit shown in this article is suitable for conventional wideband fm video with a fm sound subcarrier since most present day satellite tv transmissions use this system. a few transmissions are scrambled: they are intentionally coded so that they can not be received by unauthorised stations. due to the narrow available bandwidth and low transmitter power little scrambling can be done to the video part of the signal: video scrambling therefore only includes video polarity inversion, random line delay (discret scrambling system) or substitution of sync pulses (oak-orion scrambling system). a descrambler (decoder) for the video signal should be inserted between the pll demodulator and the am video modulator (or tv monitor). the corresponding sound channel is usually not intentionally scrambled, but other sound systems (especially digital sound-in-sync systems) are considerably more difficult to decode than the simple fm sound subcarrier system.

a new tv transmission system called 'mac' is slowly being introduced in satellite tv transmissions. the acronym 'mac' means 'multiplexed analogue components'. in the mac standard the colour and sound information is not transmitted as modulated subcarriers. the components of the tv signal: luminance, colour and sound are first time compressed and then transmitted sequentially in the time interval occupied by a single tv line. in fact the sound is first transformed in a digital format. the luminance and the colour are transmitted using wideband frequency modulation while the synchronization and the sound channels are transmited as psk bursts during the horizontal flyback interval. the advantages of the mac standard are: improved signal to noise ratio and increased bandwidth of the video signal and a number (4 or 8) of top performance sound channels. unfortunately the mac standard also has a major disadvantage: the decoder/demodulator required is very complex and expensive and it is not yet clear whether the complex and fast (20mhz clock) logic, memories and a/d and d/a converters can be integrated in a few vlsi chips to decrease the price and improve the reliability. a further disadvantage is a number of incompatible variants and subvariants of the mac standard called b-mac, c-mac, d-mac, d2-mac... the actual sat-receiver design for the mac standard is the same as for the conventional pal (or secam or ntsc) standard up to the demodulator. in addition to a wideband fm discriminator a mac receiver requires a psk demodulator. the output of a mac decoder is a rgb signal suitable to feed directly a colour cathode ray tube.

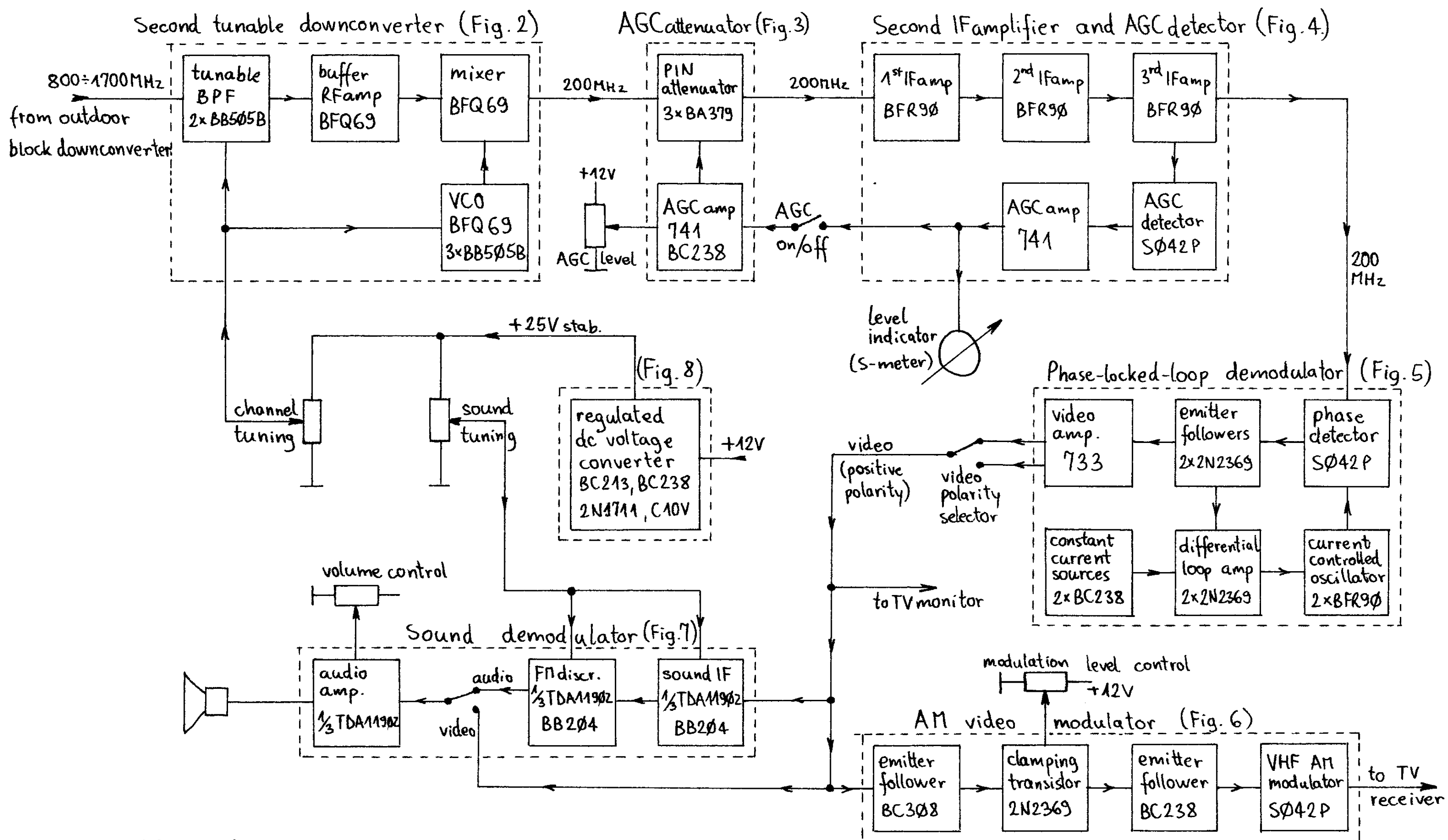

Fig. 1 - Block diagram of the sat-TV receiver indoor unit.

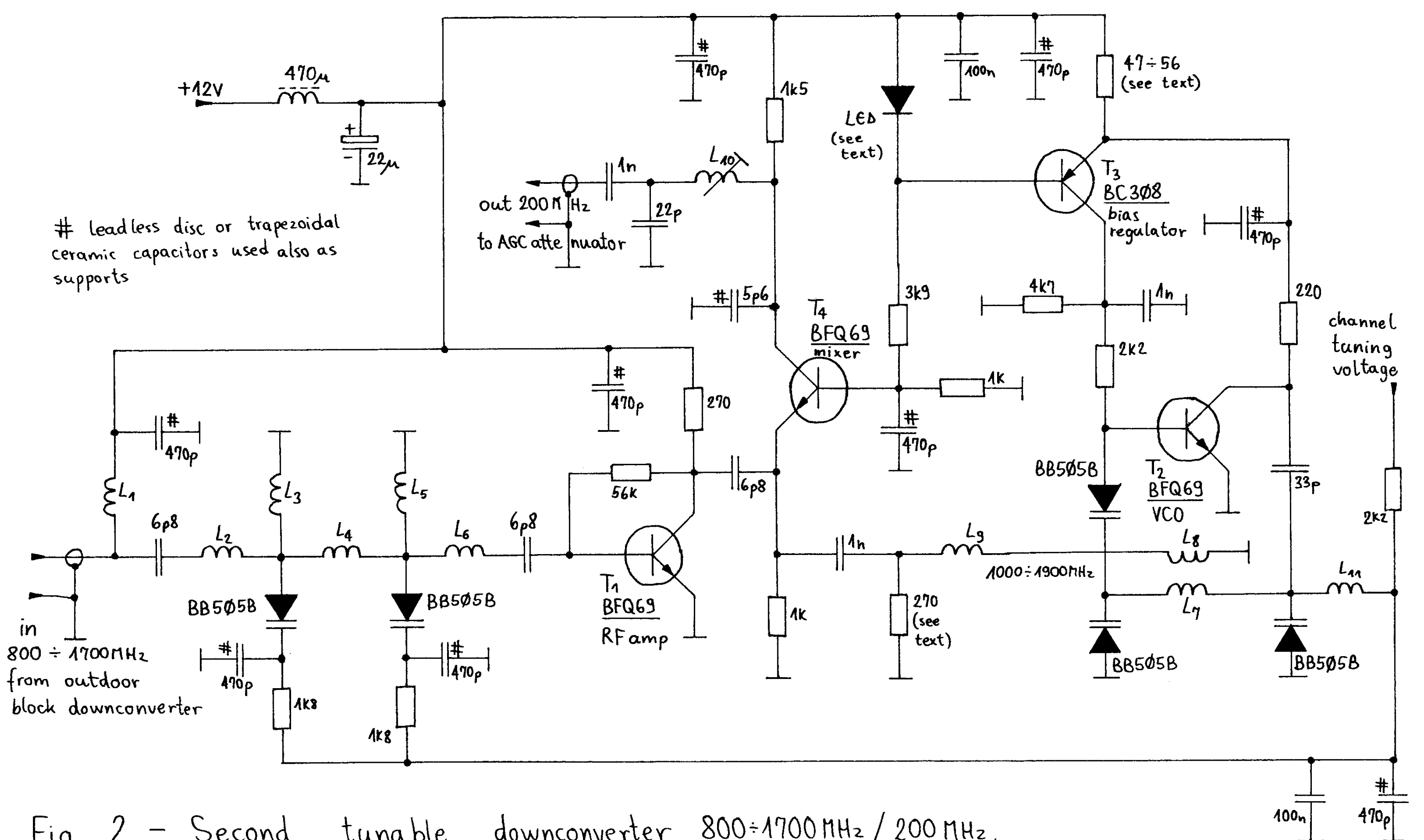

Fig. 2 - Second tunable downconverter 800÷1700 MHz / 200 MHz.

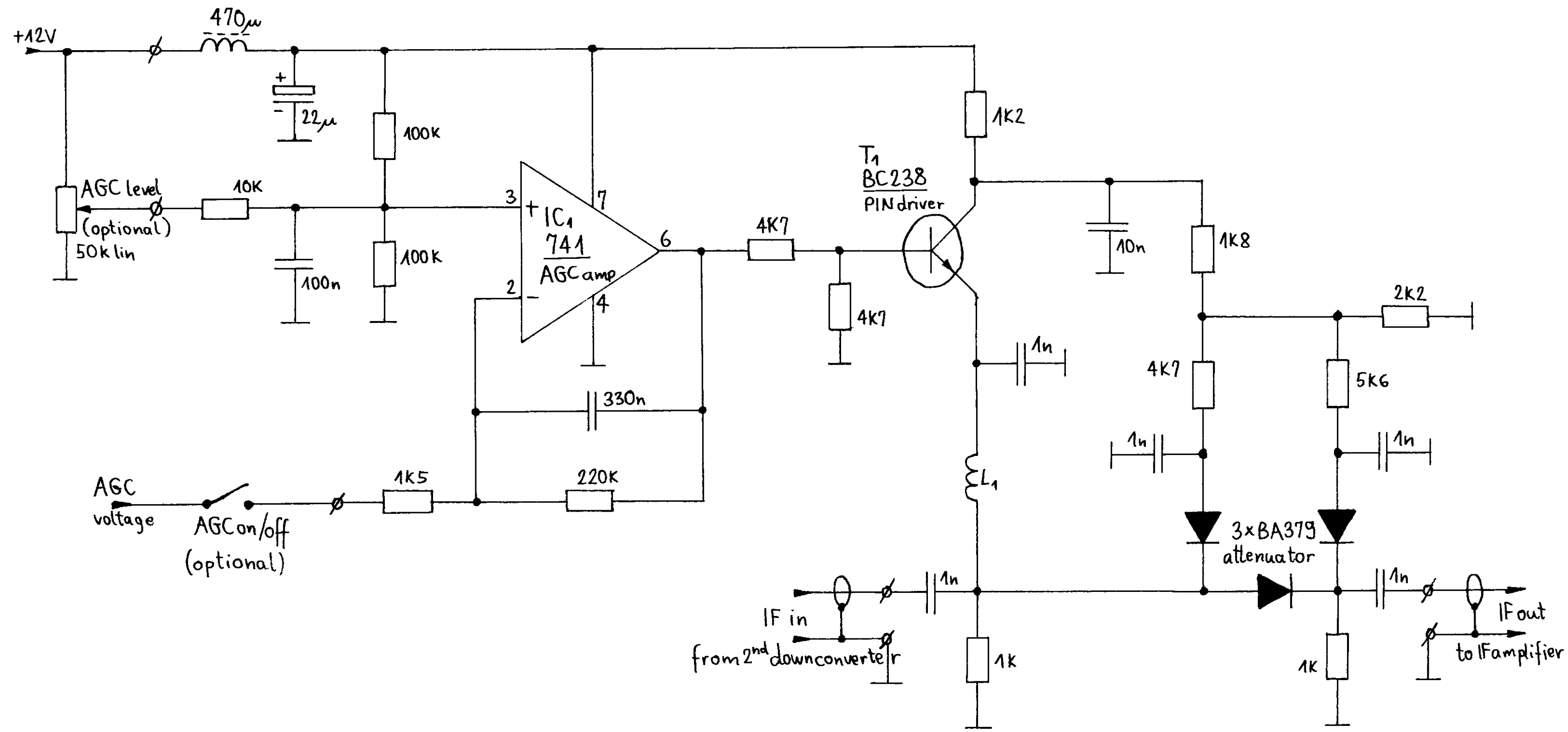

Fig. 3 – AGC attenuator.

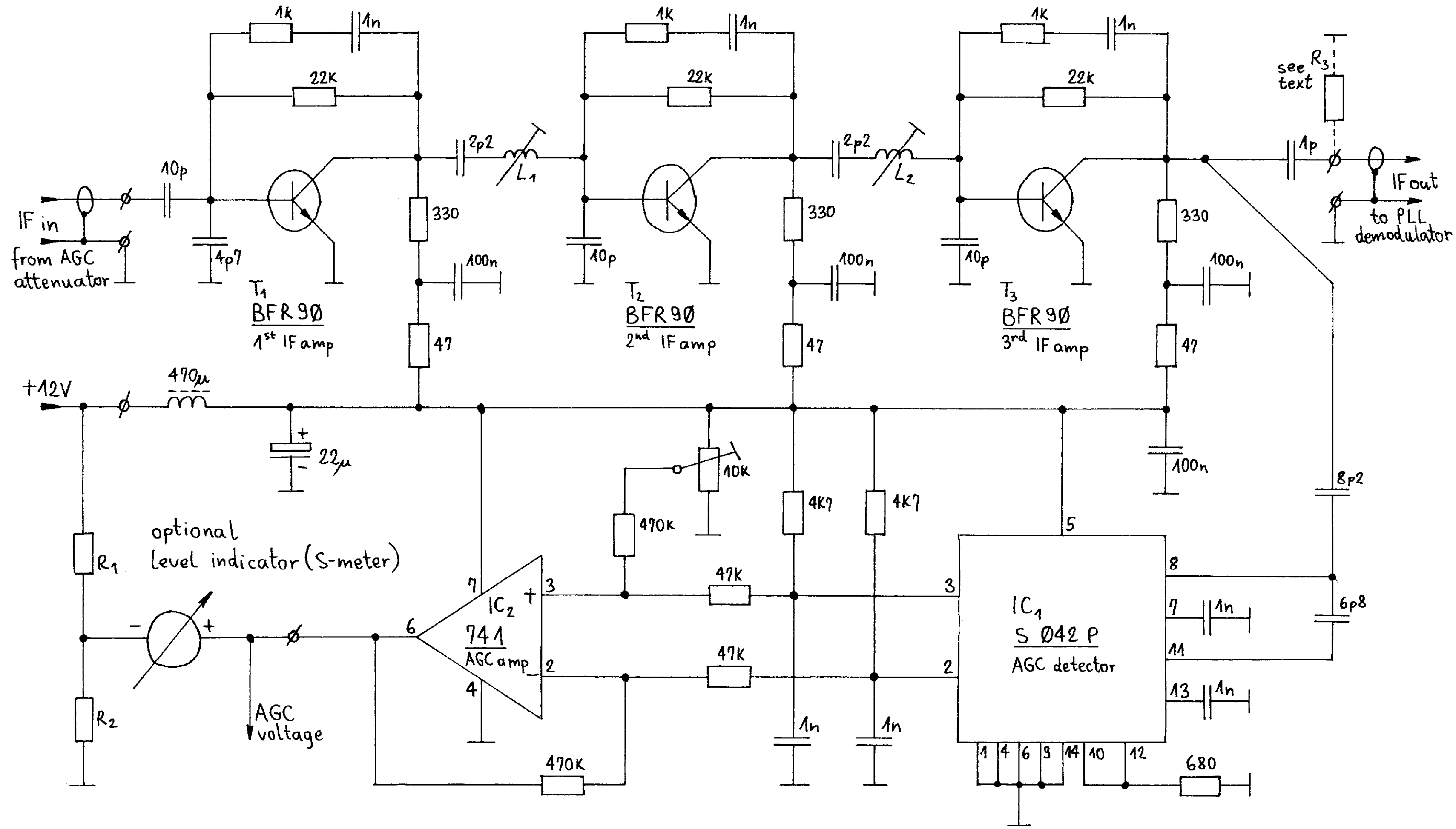

Fig. 4 - Second IF amplifier and AGC detector.

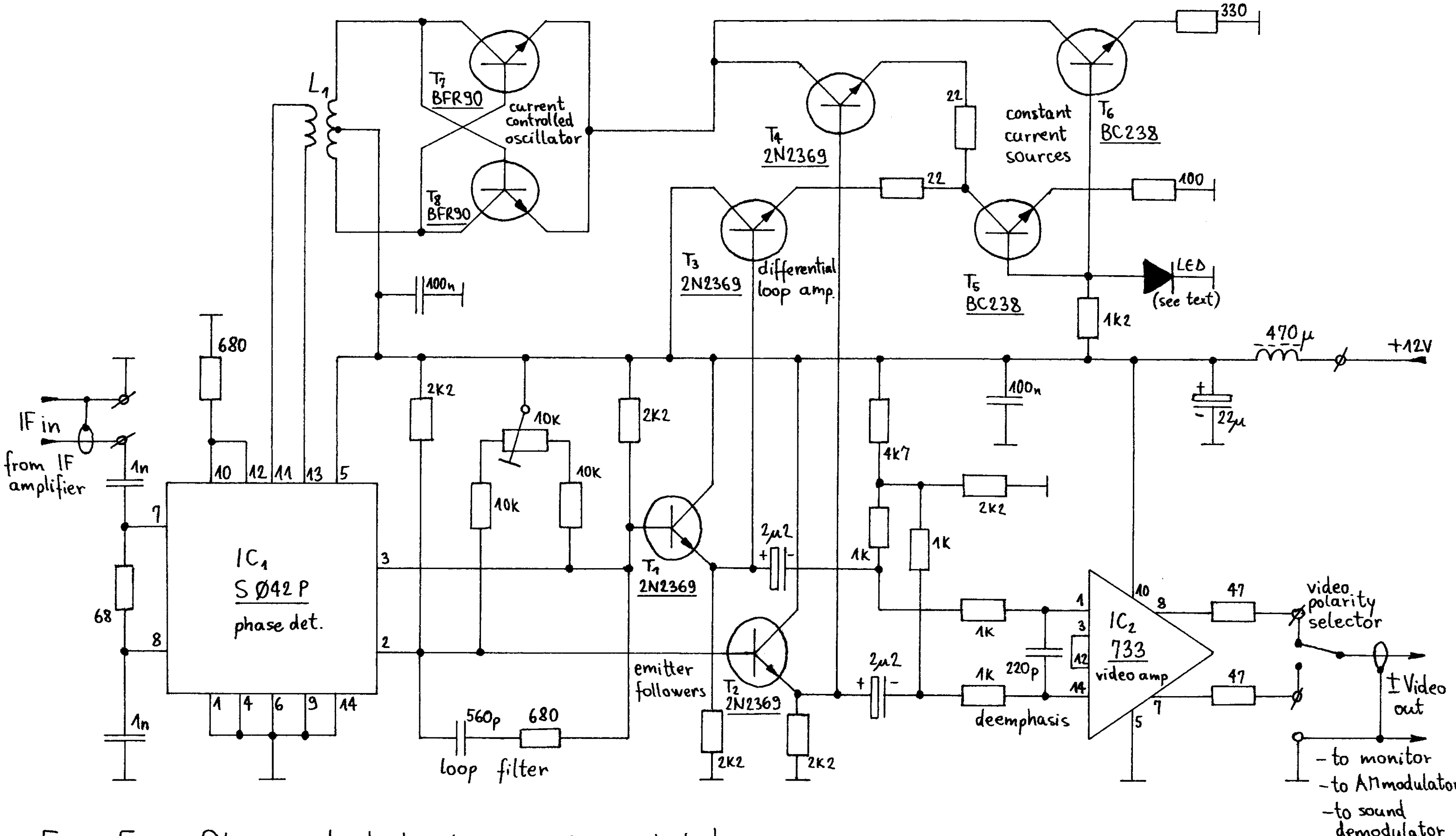

Fig. 5 - Phase-locked-loop demodulator.

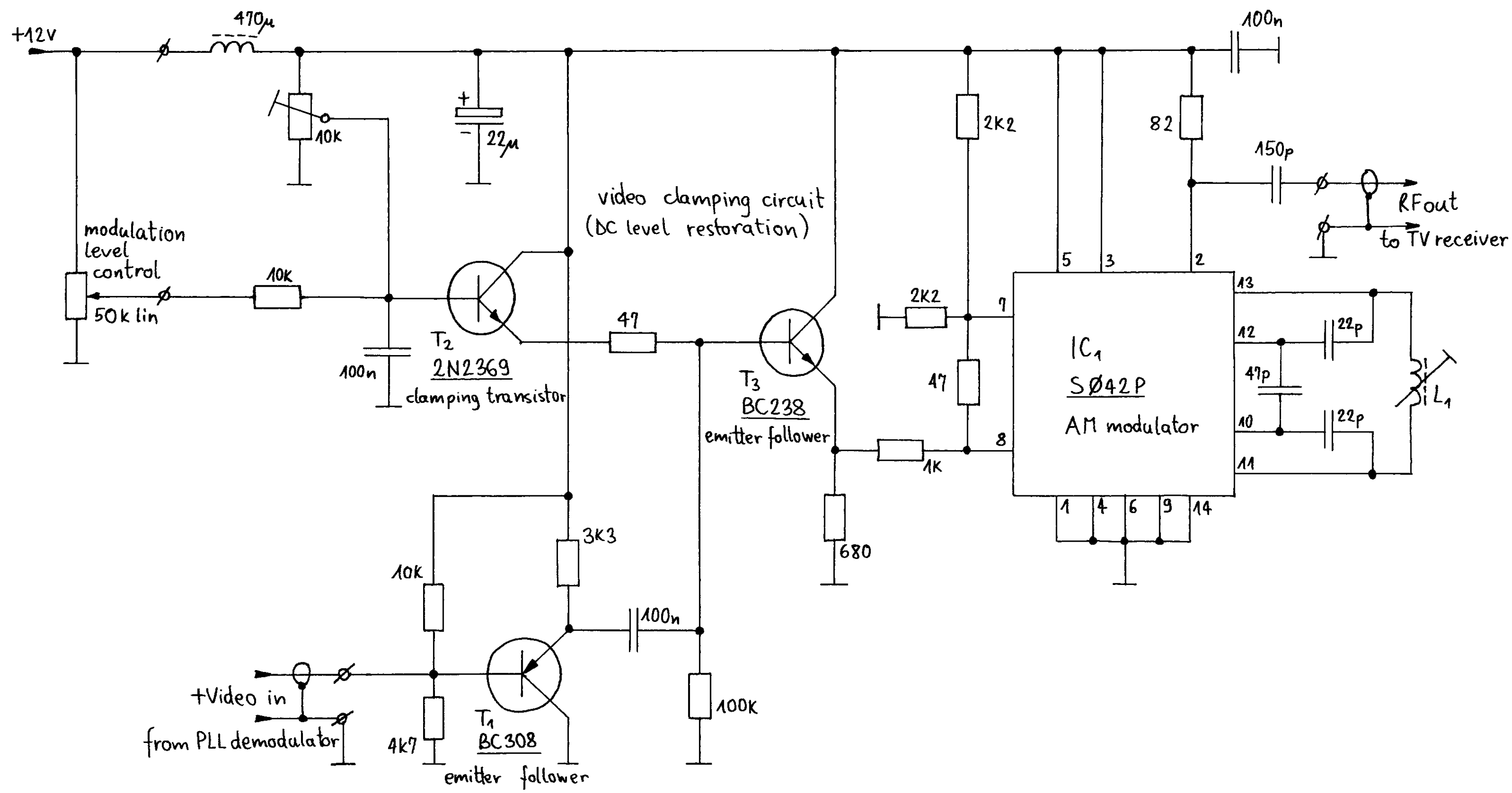

Fig. 6 - AM video modulator.

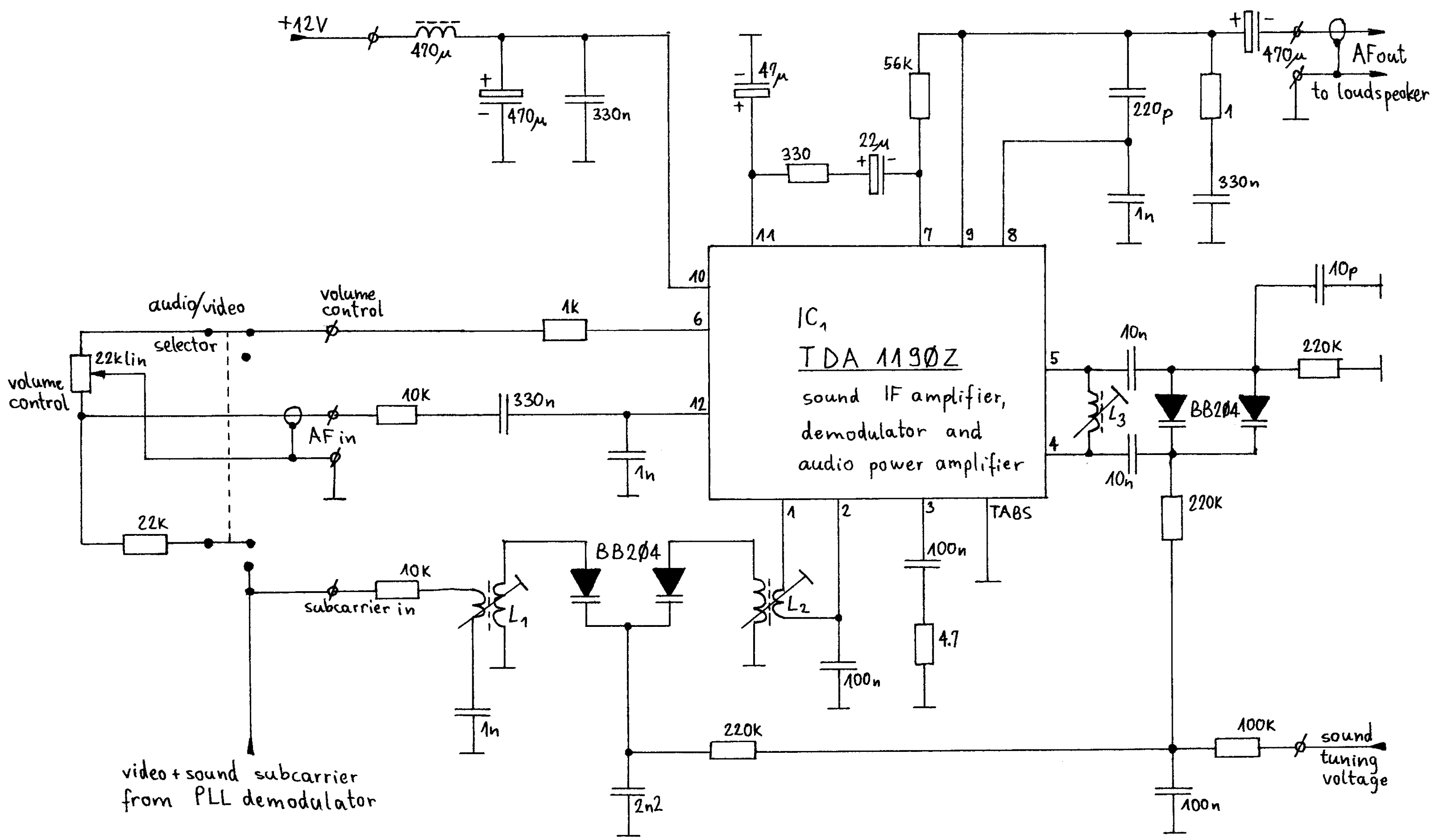

Fig. 7 - Sound demodulator.

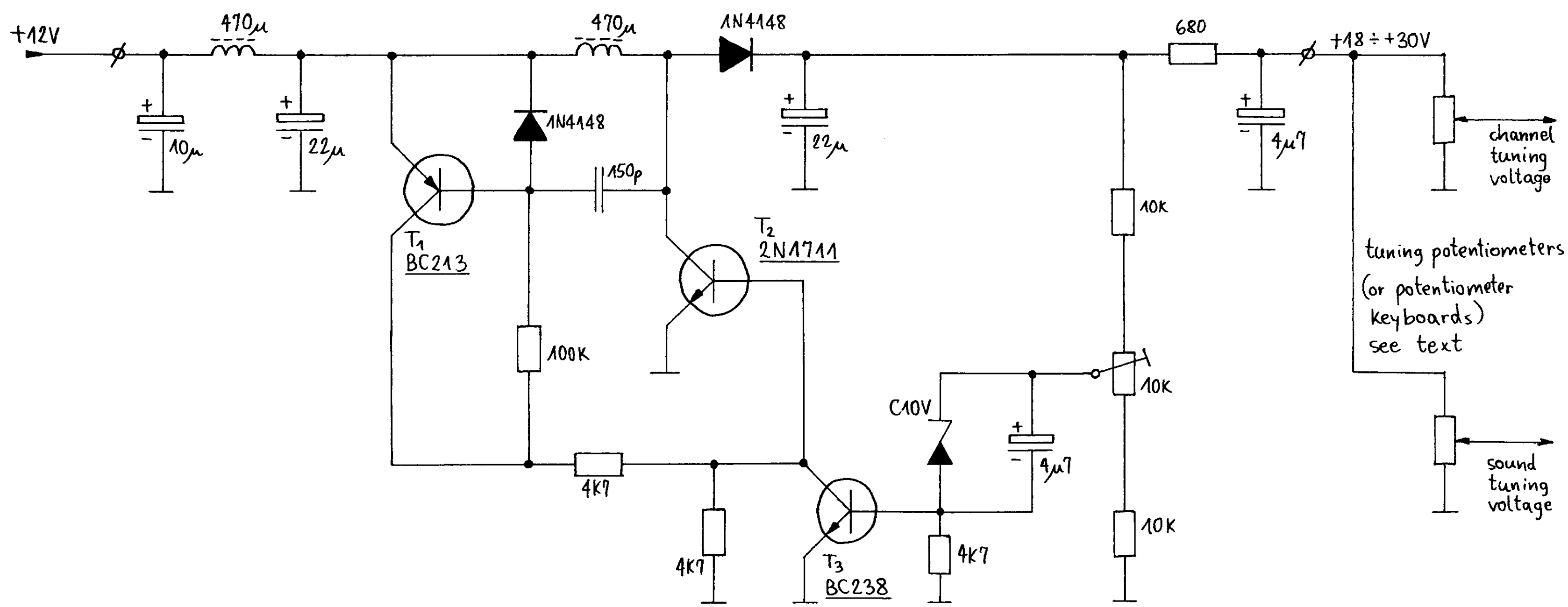

Fig. 8 – Regulated dc voltage converter.

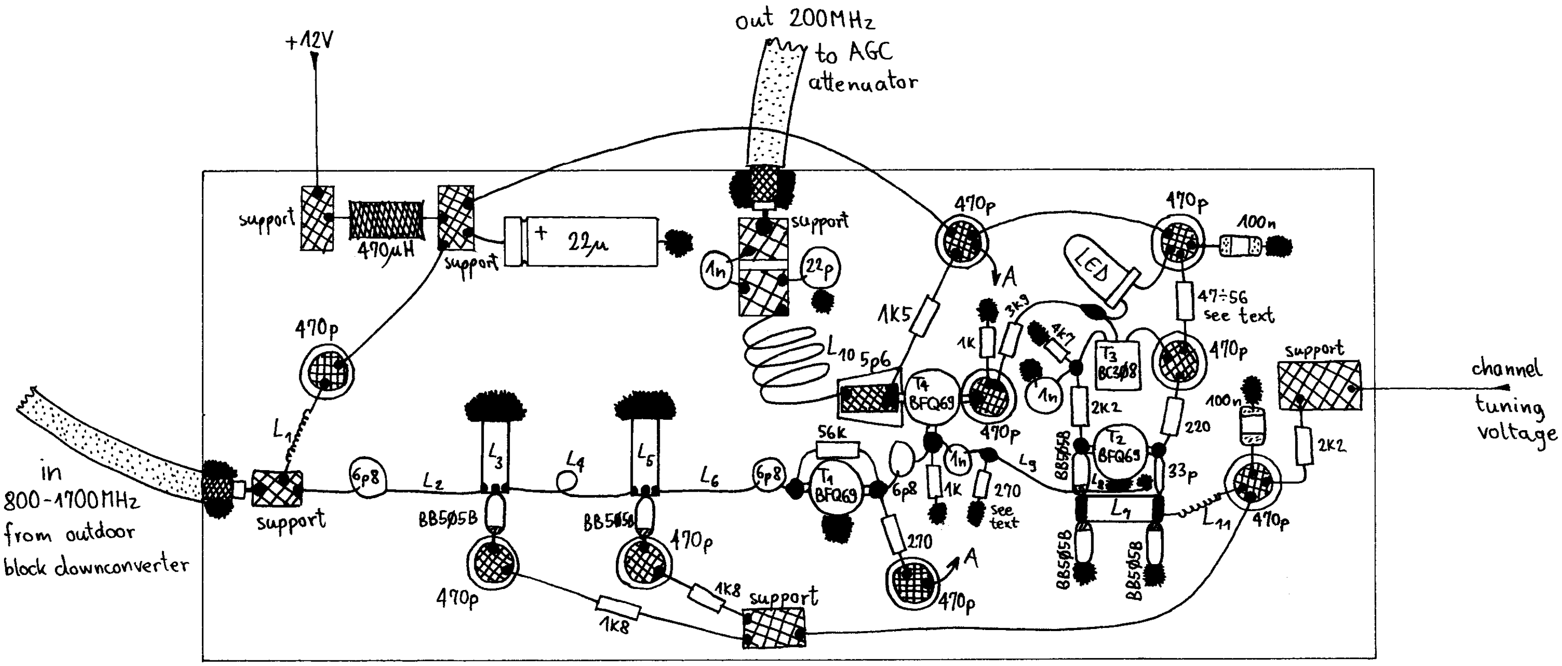

Fig. 9 – Construction of the second tunable downconverter 800-1700 MHz / 200 MHz.

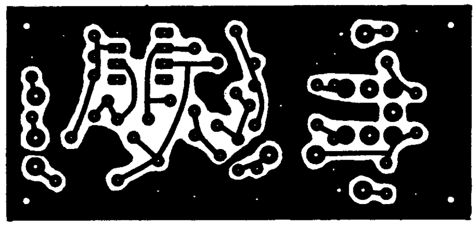

Fig. 10 – AGC attenuator printed circuit.

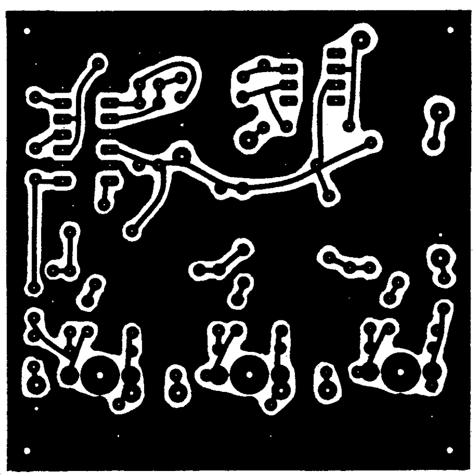

Fig. 11 – Second IF amplifier and AGC detector printed circuit.

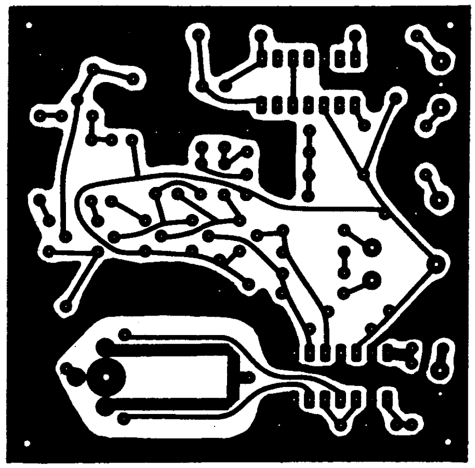

Fig. 12 – PLL demodulator printed circuit.

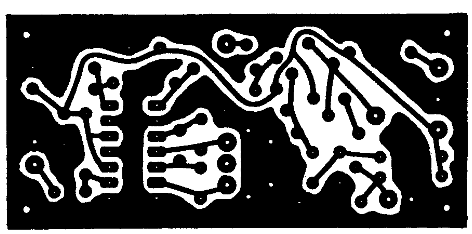

Fig. 13 – AM video modulator printed circuit.

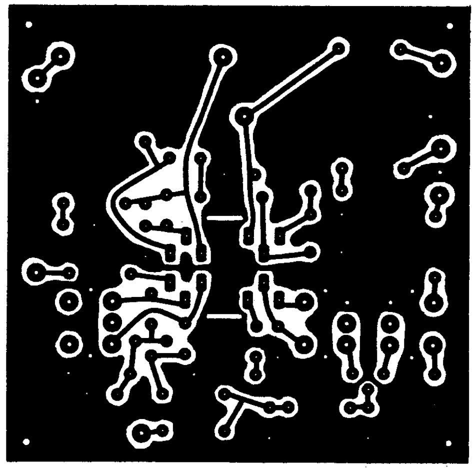

Fig. 14 – Sound demodulator printed circuit.

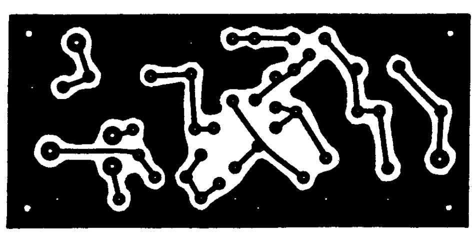

Fig. 15 – Regulated dc voltage converter printed circuit.

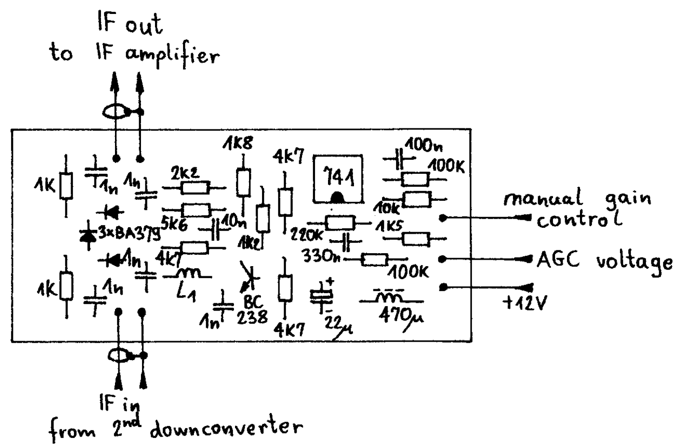

Fig. 16 – AGC attenuator component location.

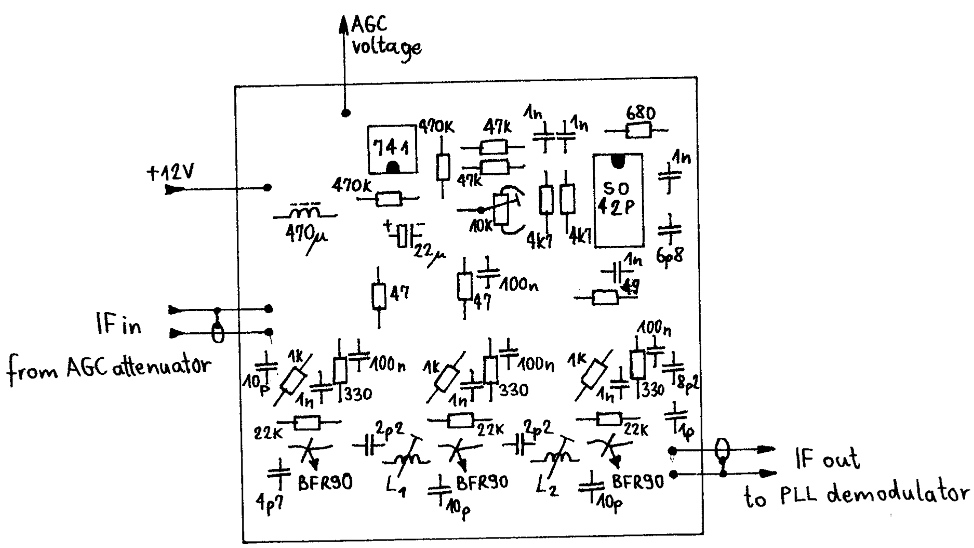

Fig. 17 – Second IF amplifier and AGC detector component location.

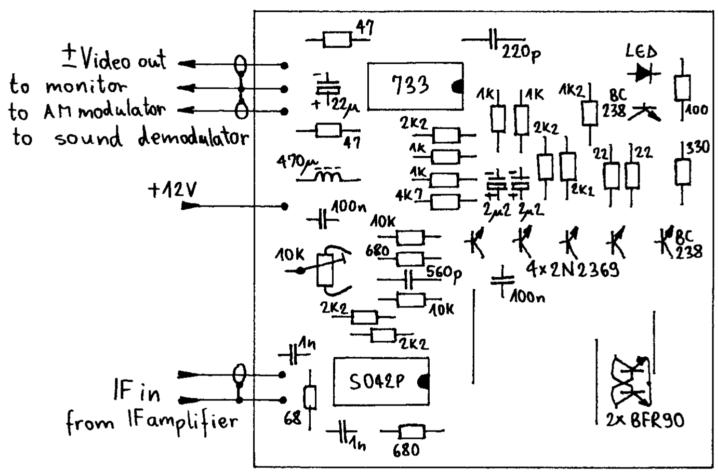

Fig. 18 – PLL demodulator component location.

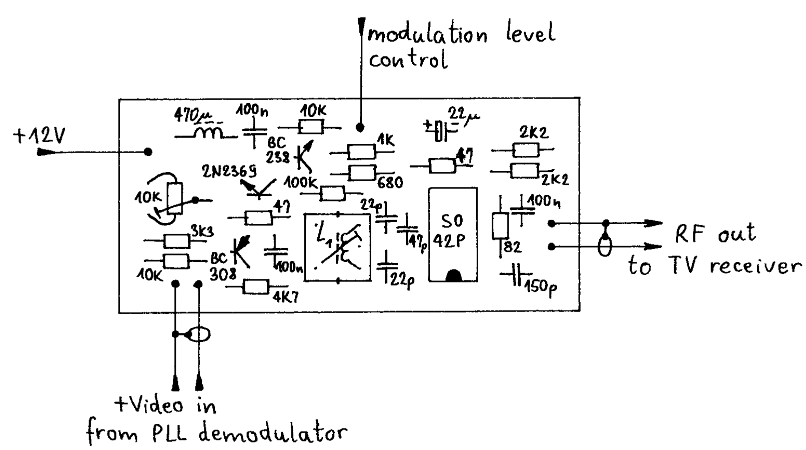

Fig. 19 – AM video modulator component location.

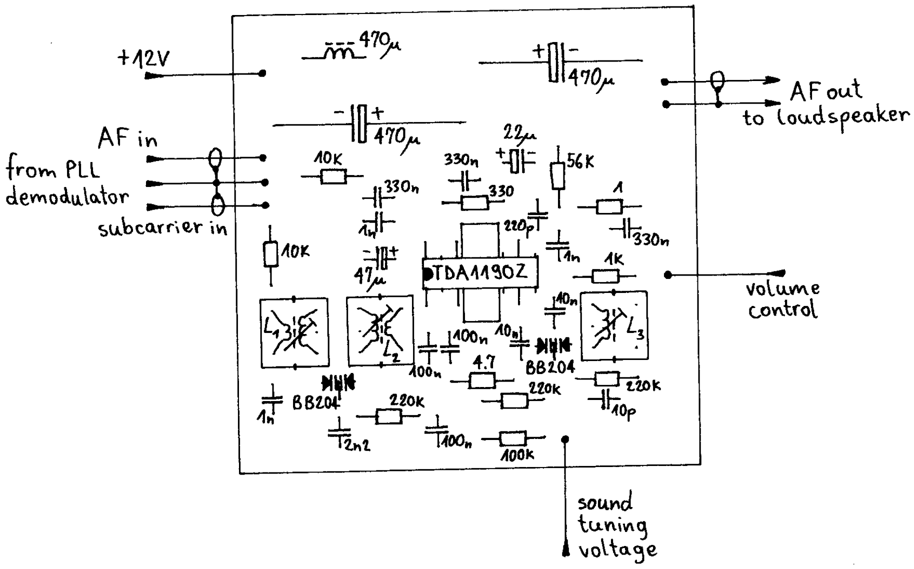

Fig. 20— Sound demodulator component location.

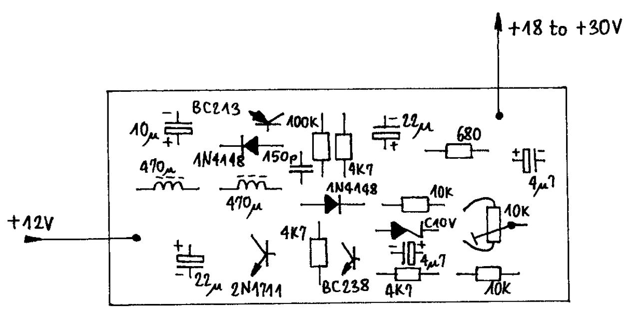

Fig. 21— Regulated dc voltage converter component location.

Fig. 5. – "Cable Network News" received with the 90cm dish

Fig. 6. – "Cable Network News" received with the 90cm dish.

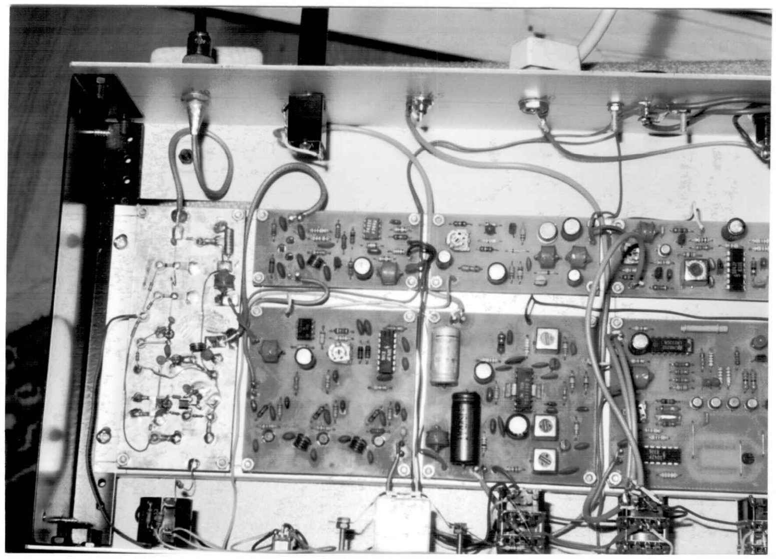

Fig. 7. - Inside of the "indoor" receiver (from left to right): second downconverter (tinned PCB), AGC, +25V supply converter and VHF AM modulator (three small PCBs), IF amp, sound demodulator and video demodulator (three large PCBs).