The Heathkit GW-21A Hand Held Germanium Transistor Transceivers.

(Dr. H. Holden. Jan. 2022)

Carry straps for the GW-21A

INTRODUCTION:

By the early 1960’s many Germanium transistor types had been produced and some were capable of excellent high frequency performance.

In Europe, the typical types were the OC169, OC170, OC171. Also the similar AF114 to AF117 series which were ultimately replaced by the AF124 to AF127 series, the former parts all being affected by Tin Whisker disease.

In the USA there were a number of 2N prefix types, such as the 2N2084, made by Amperex which had similar performance to the AF124. The RF capable transistor types were characterized by having very high transition frequencies and very low Collector to Base feedback capacitances (low Miller capacitance). This also allowed them to be used in IF amplifier chains, without the requirement for neutralization.

As one example, the AF124, in a grounded base circuit, had useful power gain of 14dB at 100MHz and was used in the front end of FM radios operating at around 87MHz to 101MHz.

In the years that followed into the 1970's, very advanced Germanium types appeared which would work in VHF & UHF TV tuners, such as the AF239 and AF240. These worked in mixer and oscillator circuits up to an astonishing 890 MHz.

Back in the early 1960's, transistor radios of many kinds were coming to dominate the radio world. These pushed the older Tube designs into the background and ultimately making them obsolete. This process was accelerated by the development of temperature stable lower noise, higher power rated Silicon transistors, which out-performed their Germanium ancestors.

Germanium transistor based hand held compact transistor transceivers, like the Heathkit GW-21A, started to appear in stores and in popular culture, on the TV and in the Movies too. Below is a frame cut from an early 1960's Voyage to the Bottom of the Sea TV show, where a Heathkit GW-21 transceiver was being used to save the day.

Simple Super-Regenerative transceivers or "walky -talky" designs for children had appeared in toy stores in the 1960's.Typically powered by a 9v battery.

These "toy" units often used single transistor stage as an oscillator in transmit mode. A small audio amplifier would amplitude modulate it. The same transistor oscillator stage then behaved as a super-regenerative receiver and the audio amplifier re-deployed to drive the speaker in receive mode. Therefore, most of the circuitry in the unit is deployed in both transmit and receive modes, hence the name "Transceiver" as the circuitry transforms and reconfigures itself for the two modes of operation.

These early transistor super-regenerative units typically operated in the Citizen's band around 27MHz.Typically, the receiver section was quite noisy (as super-regenerative receivers are) and the transmission range very limited and sometimes the results even disappointed the children, as well as the adults, playing with them.

Then, in the early 1960's, some manufacturers, such as Heathkit, started to lift up their game in the mobile transceiver design area. The clear choice for the receiver while keeping it as simple as possible, but not too simple, was the single conversion Superhet format.

Transistor Superhet receivers of the time were already known to have high gain, low noise and good selectivity in both Medium Wave and Short Wave bands, up to and above 30MHz.

Ideally too, the transmitter would also have an independent RF output stage, amplitude modulated by an audio amplifier and there would be a separate stable Crystal Oscillator driving that output stage. This two stage design limits any frequency modulating effects on the transmit oscillator.

Again the audio amplifier in the Transceiver would perform two roles; as a modulator in transmit mode and an audio amplifier in receive mode. This type of design appeared in the Heathkit GW-21 and GW21A transceivers. (These are apparently identical units, except for the transistor types used).

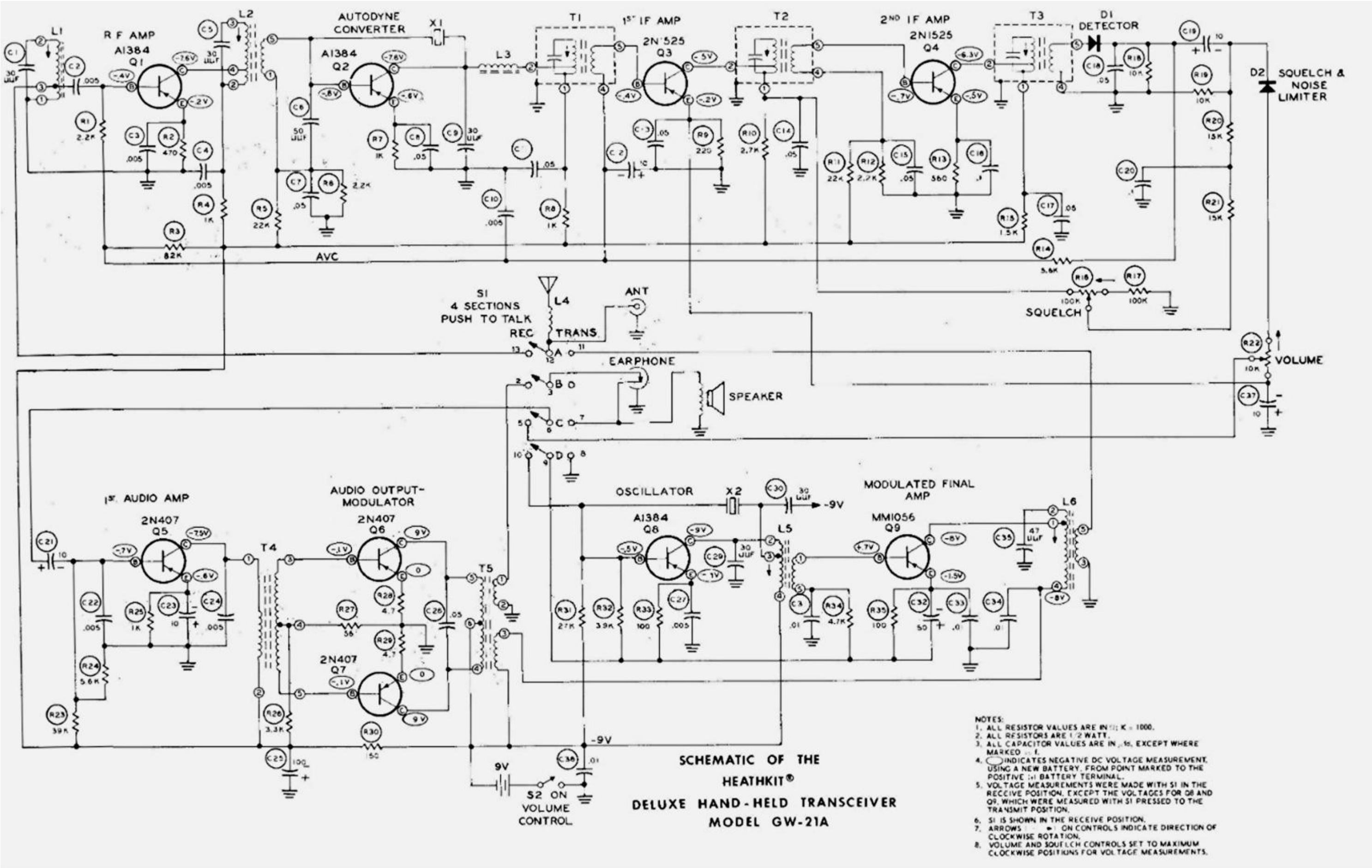
Recently I came across a pair of Heathkit's GW-21A's on eBay. I had seen these in my childhood on TV and always wanted them. So for nostalgia's sake at least, I decided to buy them and restore them. Then I could put them through their paces and find out how well they worked.

General description of the GW-21A by Heathkit's marketing department:

The GW-21 appeared in the time window of 1964 to 1969. The price per unit at that time was $39.95. In today's dollars that is about $380.00 each, not a wonder I did not have one back then.

They boasted 9 transistors, 2 diodes and a single channel crystal controlled system, using two crystals per unit. Separate crystals were used for the receiving and transmitting oscillators. On-off/volume control, Squelch control, push to talk button (PTT), an earphone jack, an external antenna jack and integral Whip antenna. All powered by a single 9V battery.

The schematic of the GW-21A is shown below.



While I was able to easily find the schematic for the GW-21A, the original Heathkit manual was more difficult. Possibly, one reason why the manual for the GW-21A is difficult to acquire online is noted below. This was an interesting revelation, because normally in the field of Amateur Radio, or CB radio, there is a spirit of sharing and cooperation.

The earlier GW-21 model and the Riders service manual for that model is available, as it pre dates1964, but the GW-21A manual does not. I found these remarks while online searching for the GW-21A manual:

On Heathkit Manuals: In October, 2008, the intellectual property rights to Heathkit legacy products were purchased by Don Peterson of Data Professionals of Pleasanton and it appears Mr. Peterson has been very aggressive in stopping on-line manual downloads and sales. Downloadable Heathkit manuals are no longer available at BAMA (or at the mirror) or from other sources on the web. Data Professionals offers printed copies of some manuals but at this time none are available for any of the Amateur Radio products ever offered by Heathkit. ***Update:*** Research by Rich Post, KB8TAD, indicates Heathkit manuals from prior to 1964 remain in public-domain because the copyrights weren't renewed by Heathkit.

CIRCUIT DESCRIPTION:

Referring to the schematic, on the receiver side, the design is of a conventional Superhet with an RF stage, designed for one frequency reception.

The RF input from the Antenna is passed, after appropriate impedance matching, to Q1, the RF amplifier. The Crystal controlled local oscillator, called an Autodyne Converter, or Mixer-oscillator Q2, runs above the received frequency.

The oscillator stage receives the signal from the RF amplifier and the mixing products appear in Q2's collector circuit. Sum & difference frequencies of the incoming carrier wave and the oscillator wave appear because the non linear mixing results in products of these two waves. The first IF transformer T1 effectively filters off the difference frequency of 455kHz and feeds this to transistor Q3, the first intermediate frequency (IF) transistor.

Typically, in most Superhet radios, with a 455kHz IF channel, the receive oscillator frequency runs 455kHz higher than the incoming carrier wave. In my GW-21A radios, the transmit crystal and transmit frequency is 27.085MHz (Channel 11 of the Citizen's band) and the receive oscillator crystal in the converter stage is 27.540 MHz.

From Q3 the IF signal passes via T2, Q4, then T3 in the IF amplifier to the detector diode D1, where the amplitude modulation is recovered. In addition an AGC voltage is generated by the detector, filtered and fed back to Q3 and Q1.

Of note, in a set with PNP transistors, the AGC voltage is positive going, with increasing signal strength. This tends to take the transistors which the AGC is applied to, out of conduction, with a shift towards a lower gain condition, with increasing received signal strength. Essentially the AGC system is a long time constant negative feedback loop.

The AGC's time constant, or frequency response to abrupt changes in received signal level, along with circuit resistances, is set by the value of the 10uF electrolytic capacitor C2. (With very high signal levels, the voltage on a transistor radio's AGC capacitor can reverse polarity, so generally I replace the AGC capacitor with a Bipolar or Film type).

The recovered modulation (audio signal) then passes via the "squelch diode" D2, to the volume control. D2 is set up with a variable DC voltage applied to its cathode from the squelch control. This allows the diode to be cut off, progressively uncoupling the audio feed to the volume control, unless the dynamic signal peaks are large enough to overcome the diode's voltage drop.

Testing shows that in the "un-squelched" condition, the diode has a 0.43V forward bias, this is more than enough to have the germanium diode in solid forward conduction. With the knob in the full "squelched" condition, the applied forward bias is very close to zero volts, so the recovered audio signal from the detector has to overcome the diode's forward drop to pass through to the audio amplifier.

The audio is then passed via the press to talk switch (in its un-pressed or listen condition) to the input of the Audio Amplifier stages.

The audio amplifier is typical of the design of that of typical transistor radios of the era; a class A driver stage, driving the bases of two output transistors in Class B. The output transistors have just enough initial bias to avoid cross-over distortion. These simple amplifiers are energy efficient with a low quiescent current and generally suited to battery operation. The only difference here, being that the output transformer has an additional winding to amplitude modulate the power supply to the RF output stage, when the unit is in transmit mode.

RESTORATION OF THE TWO GW-21A UNITS:

Both the units arrived in good condition and fortunately there was no evidence of previous repairs or modifications. Having worked on a number of items of this vintage, with Germanium transistors, I decided to start with a standard protocol, by checking the electrolytic capacitors & replacing them where required.

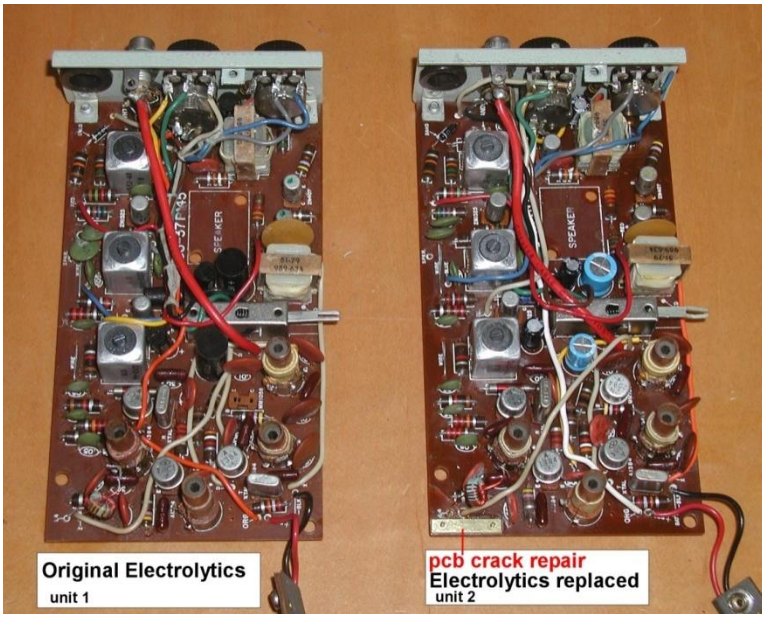
The 7 electrolytic capacitors in each unit were removed for inspection and detailed testing. There were some abnormalities. All had leakage values over 100 times higher than a reference new electrolytic of the same value. Interestingly, the ESR of all of them was within normal limits. The uF values were reasonable, except for the axial 10uF electrolytics, which interestingly read around 38uF on the capacitance meter.

Due to the high range leakage values though, all of the electrolytic capacitors were replaced.

I also quickly determined that the 100 Ohm resistors in the emitter circuits of the oscillator and RF output transistors out of spec at 135 Ohms each. So these got replaced. All the other resistors were in good order and in spec.

In addition in one of the units, call it unit 2, had a cracked section on the lower corner of the phenolic pcb. This was strengthened with a small 2mm thick brass plate tapped with threaded holes for 1.6mm brass screws to secure it.

The potentiometers and transistor sockets and PTT switch were cleaned with CRC's CO contact cleaner and then lubricated with Inox's mx-3, which I have found better than using a combined cleaner-lubricant product. Inox mx-3 is a very high purity oil and I have subjected it to a number of experiments on various metals and it is my preferred lubricant for restoration work.



Prior to attempting testing and alignment, I have a standardized approach, when transistor sockets are present, checking the transistors for gain and noise first.

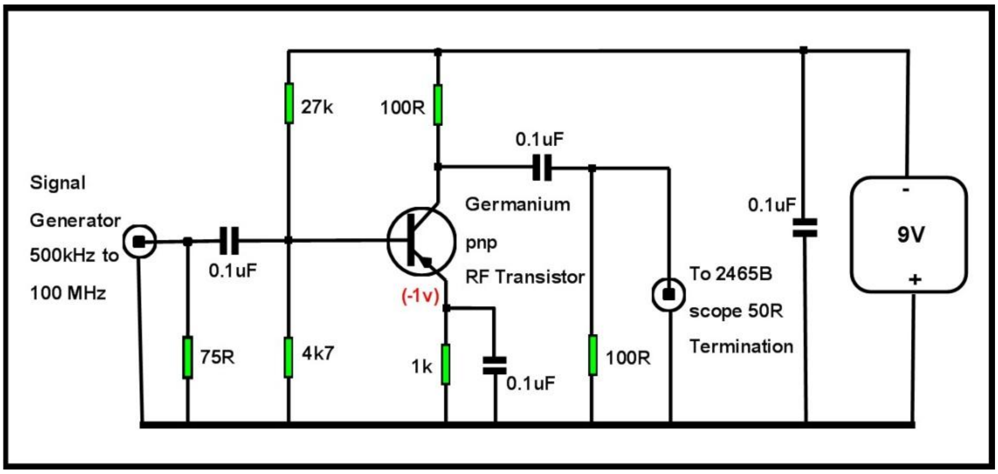
For the audio transistors though, I check these in circuit. The speaker is replaced by a 10 Ohm dummy load (the original speaker is a 10 Ohm type). The scope connected across that dummy load and a test audio sine wave signal from the generator applied to the input (driver transistor/volume control area).

It is easy to see if the audio transistors are ok in this sort of amplifier. If either output transistor is unwell it unbalances the output and the sine wave becomes asymmetric. Also the driver transistor is easily checked against a known good Germanium pnp audio driver transistor, for example an AC126. The output transistors can be verified against known good AC128 types.

Also one final check is to compare the two audio amplifier sections for gain and power output, comparing the two GW-21A units. I was satisfied that the audio stages were normal in both units and that all the original audio transistors, RCA 2N407 types, were perfectly normal.

The radio frequency transistors are a different matter. I check these out of the radio in a test jig-circuit setup with a socket, so as to examine their gain and frequency response up to 100MHz. This is a way of screening out defective transistors.

I use a Philips PM5326 RF generator which has a 75R output resistance and a Tek 2465B scope, set on its 50R input resistance option, to assess the transistors. The transistors are placed in a simple test jig, in a socket to evaluate their basic performance and compare them to some excellent AF178, 2N2084 and AF124 transistors which I have in my stocks as well as comparing the same types from the two GW-21A units with each other:



The test circuit quickly screens out noisy and weak transistors.

On testing, the 2N1525 IF transistors all had similar properties, with nearly identical gain to an AF124 reference transistor below 1MHz, and unlike the AF124, where the output amplitude in this particular test jig drops to 50% at 70MHz, the 2N1525's output reduces to 50% at about 10MHz.

The 2N1525 transistors are just satisfactory enough (low enough collector to base feedback capacitance) to work in an IF amplifier without the requirement for Neutralization. You will notice from the GW-21A schematic, it is a non-neutralized 455kHz IF.

The A1384 transistors in the RF stage, converter stage and transmit oscillator stage were all good in both units.(Note: these are not 2SA1384's, they are an Amperex part). In the test jig their output drops to 50% at around 50MHz. They are higher frequency capable than the 2N1525 transistors used in the IF amplifier, as they have to be, for the role they play operating in the 27MHz stages.

(Comparing known good reference transistors in the test jig, an AF178 transistor has an output that drops to 50% at about 110 MHz and the AF124 drops to 50% at about 70MHZ and an Amperex 2N2084 to 50% at about 50MHz, similar to the Amperex A1384 transistor).

Then there were the two RF output transistors to test for each unit, the somewhat mysterious Motorola MM1056:

I was unable to find the original Motorola data sheet on these, specifically the transition frequency. Though some basic data found online, suggesting they were probably similar to a device such as an AF124. I also posted on the Antique radio forums, with no luck finding the original Motorola data sheet. The logical place to find it would be in an early 1960's vintage Motorola transistor data book.

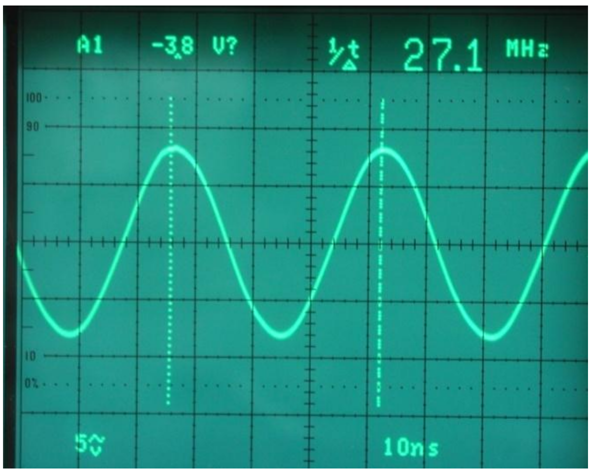
One of these transistors was defective and its leads had been cut down by someone in the past. The junction was damaged and badly leaking. The other transistor from the other GW-21A unit was good. Testing the good one, in the test jig it was clearly capable of very high frequency performance, being very similar to the AF178 with its output dropping to 50% by about 110MHz.

However, during alignment and testing of the transmitter section of the radios, I elected to replace the MM1056 transistor in both units with the Amperex 2N2084, as it gave more stable results with slightly higher output.

I also found that there were some capacitive coupling effects to the transistor body. In these Heathkit radios, all of the transistor sockets are 3 pin. There is no shield connection. I found the quick solution for the 2N2084, was to simply connect its shield (case) wire to its emitter wire (which is at common, from the radio frequency perspective). This solved the problems of higher frequency parasitic oscillation I had observed with the original MM1056 and the Amperex 2N2084, when the body of the transistor was floating in both cases.

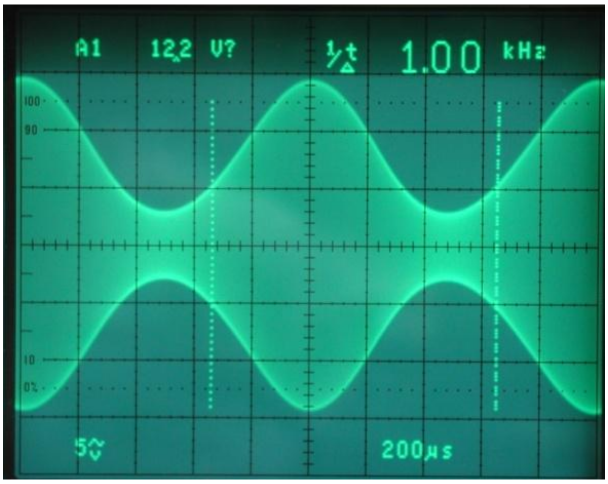
After alignment of the transmitter section, L5 & L6, the scope recording below shows the output of the transmitter, with the antenna retracted into the unit and the scope connected to the base of the Whip antenna in the unit. The measured voltage was about 16vpp. With the antenna up, the amplitude drops to about ½ that at 8v pp.

Of note, if L5 is peaked for maximum power output and then the slug is unscrewed further, it can result in the oscillator dropping out or failing to start when the push to talk button is pushed. So it is best to peak it just a little on the opposite side of the peak, with the slug a little further into the former.

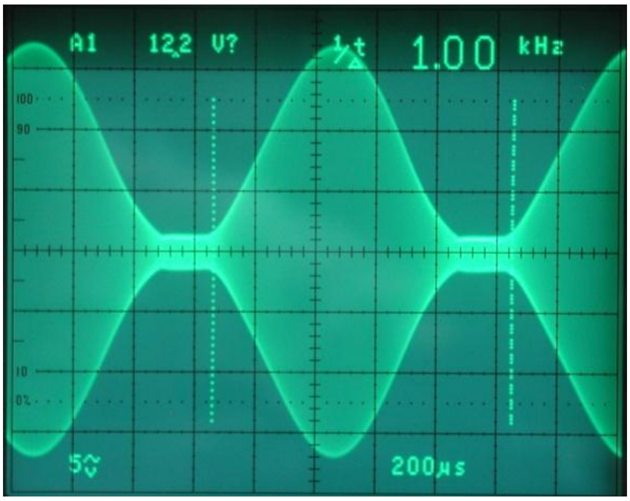


In lieu of talking into the speaker for testing, with the speaker replaced by a 10 Ohm dummy load and in the transmit mode, a 1kHz sine wave modulation signal was applied from a signal generator.

The generator output was set on 0.5V peak or about 350mV rms and a series 3.3k resistor used to deliver the signal across the 10 Ohm dummy speaker resistance. This corresponds to only about 1mV rms of signal to the input of the audio amplifier. This was the result with the carrier now at the antenna base of about 28Vpp on the modulation crests:



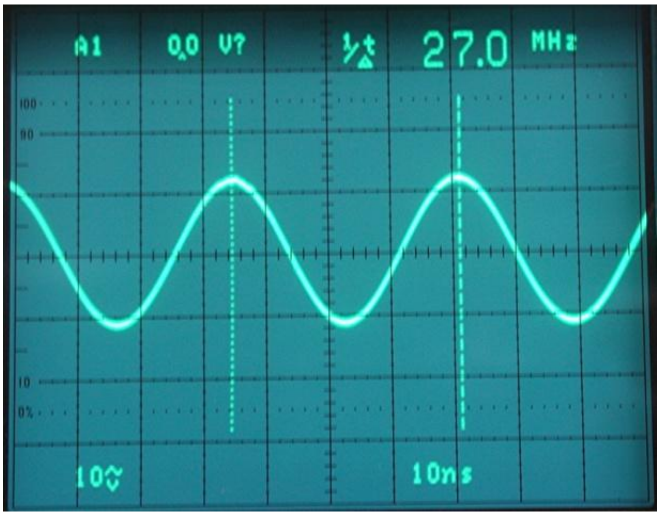
Increasing the modulation signal level from the generator, the RF output stage clipped fairly softly and the carrier was not modulated to zero. This occurred before clipping in the audio amplifier. I was quite impressed by the feature of the fairly soft carrier clipping and residual carrier remaining:



RF OUTPUT POWER of the GW-21A:

I had read on the net that the output power of this radio was 100mW, but I wanted to check for myself.

The methods used here to assess the output power results in an approximate estimate. I also noticed, that after working on these radios for some time, the 9V batteries I had been using, which had previously seen some use before, had dropped down to 8V. So I repeated the carrier output test with fresh batteries:



As can be seen from the above recording, with fresh batteries the RF output at the antenna base (with the antenna retracted) comes up to 12v peak or 24v pp. And it is about double this at 100% modulation. Also, I found that raising the whip antenna caused the voltage level to fall to approximately 50%. This suggests that very likely, the antenna impedance has been reasonably well matched with its loading coil to the RF output stage.

I decide to test with various load resistors at the antenna's base, with the antenna retracted, to find which resistance also lowered the RF level to 50% so as to make a very rough estimate of the antennas impedance at full extended length. A 680 Ohm resistor resulted in the level dropping by 50%, much as extending the antenna does.

Looking at the voltage then, with no modulation the voltage developed across the 680 Ohm load was 6V peak or 4.24V rms and at full modulation about 8.48v rms. Therefore, the peak envelope power (PEP) delivered to the 680 Ohm dummy load resistor (or the fully extended antenna) is approximately 8.48^2 /680 = 106mW at full modulation. And with zero carrier modulation, the RF output power is ¼ that, at about 26 mW.

It appears likely that the suggestion that these GW-21A radios had a 100mW RF output, was probably referring to a PEP measurement, not an unmodulated carrier wave power which is ¼ of the PEP.

In another attempt to estimate the RF power output, I tested the signal out of the external antenna jack. The output impedance here appears very low. Unloaded and unmodulated it has about a 4v pp signal. Loaded with a 15 Ohm resistor, it drops to 2v pp (or 0.7v rms), which corresponds to around 32 mW (unmodulated) into 15 Ohms. I made a 1:2 turn's ratio (1:4 impedance ratio) ferrite RF impedance matching transformer and found, unmodulated, it could deliver 28mW into a 50 Ohm load, or around 112mW PEP at full modulation.

RECEIVER ALIGNMENT:

The receiver alignment was fairly straightforward. Firstly the IF was aligned. This was done by connecting the scope across the 10 Ohm dummy speaker load resistor and applying the signal from a Philips PM5326 RF generator to the antenna connection.

The generator being set for an output on exactly 455kHz and a carrier modulation level of 30% and the volume control set at maximum. The receive crystal X1 was unplugged to disable the converter. Enough level was provided so the recovered signal was visible just prior to significant AGC activation and the IF transformers T1, T2 and T3 were peaked.

After this the receive crystal was plugged back in and the generator set for 27.085MHz and the receiver aligned for maximum gain by adjusting L1 and L2. After that was done, the generator was physically disconnected. A small antenna was attached to the generator output and L1 and L2 adjusted again with the GW-21A's antenna extended with the unit some meters from the generator. This is done in case the attachment of the generator had caused some de-tuning effects, but it turnout out the slugs of L1 and L2 were in the correct positions.

Signal is resolvable or audible out of the noise floor when the generator's variable Attenuator was in the region of -70 to -80 dB. With noise and signal about equal to the ear, the attenuator was on -75dB. The PM5326 generator, on 0dB applies 50mV rms into 75 Ohms and with a high Z load applies about double that. This suggests that the receiver is able to resolve a signal of about 17uV out of the noise floor.

Once the receivers were aligned it was time to try them out. In practice, on full volume on the control, there is moderate audible noise. Nothing as severe as a super-regenerative radio though. The squelch control works well, not like a typical squelch that suddenly kills the noise, its effect is more gradual. I could hear intermittent transmissions of people speaking at times, with American accents, making me wonder if that was some sporadic short wave transmission on CH11 from overseas. In any case, the receiver appears very sensitive indeed.

So far I have tried these radios with about 100m separation with very good results. I am going to perform a maximum line of sight test on them soon.

BATTERIES:

The battery compartment is a little large for a typical 9V battery. So I modified some 6 AAA cell holders and fitted them with a 9V battery power clip. It pays with these holders to tape the batteries in. I use Scotch 27 fiberglass tape as it can be re-used a few times and it stops the holders sliding around too. The photos show the relative size:

It was necessary to add some soft packing into the battery compartment so the batteries would be a snug fit.

The photo below shows the two restored units with the batteries fitted.

SUMMARY:

The GW-21A’s are a remarkable early Germanium transistor hand held transistorized transceiver. While they don’t have a spectacular RF output power, only 100mW PEP, compared to modern transceivers, they make up for that by having a very sensitive Superhet receiver. They are far from a “toy radio”. It would have been a dream to have owned a pair of these of these as a boy, back in the 1960’s, when most of the transceivers children could get their hands on were poorly performing noisy Super-Regenerative types. These sorts of transceivers make an interesting restoration project and replacement or equivalent Germanium transistors are still available if they are required.

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