Ten-Tec 1254 Receiver AGC Modifications

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Abbreviations used in this article	
AGC:	Automatic Gain Control
AM:	Amplitude Modulaton
IF:	Intermediate Frequency
LED:	Light Emitting Diode
RF:	Radio Frequency
SMD:	Surface Mounted Device
SSB:	Single SideBand
SWL:	ShortWave Listening

1. Introduction

This article describes a modification that allows the automatic gain control (AGC) function in the Ten-Tec 1254 receiver to be turned off or on. This modification enables the receiver to be used for radio astronomy applications in the high frequency band without changing its regular application as a shortwave listening (SWL) receiver.

2. Receiver description

The 1254 is a compact, microprocessor controlled, synthesized, dual-conversion superheterodyne, general coverage receiver available as a kit (USD205 in July 2012 (figure 1). Specifications are provided in the Appendix, and additional information can be found at: http://www.tentec.com/products/Digital-Readout-Superhet-Receiver-Kit.html). The receiver uses many transistors, several integrated circuits and a 7-segment light emitting diodes (LED) frequency display, all of which now would be considered obsolete technology. This does not detract from the receiver's popularity or from its performance, which is considered quite good for its price.

Figure 1 ~ Ten-Tec 1254 receiver in operation. The 1254 tunes in steps of 5 kHz in AM mode or 2.5 kHz in SSB mode (LEDs to the right of the frequency display indicate the mode). The Clarifier control is used for fine tuning. The decimal point on the far-right of the frequency display indicates variable frequency tuning (on) and memory tuning (off). A convenient feature is a Fast tuning mode in which the tuning dial changes the frequency in 0.1 MHz steps. Up to 15 frequencies can be stored in memory using the MW (memory write) function key. The receiver has a built-in speaker, which is muted when an external speaker, headset or soundcard is connected to the speaker jack on the lower-left-front panel.

A frequent complaint seen in online forums is self-generated noise (birdies) from the LED display multiplexing circuits. I did not find birdies to be a significant problem in my application as a tunable receiver for solar and Jupiter reception. However, a future article will describe measurements and additional modifications that reduce birdies and improve upon the receiver's existing performance.

3. Automatic gain control

The purpose of automatic gain control in a receiver is to limit the audio output variations caused by changes in the RF input due to, for example, propagation or close proximity of the transmitting station. It also prevents saturation (overload) of the receiver radio frequency and intermediate frequency (RF and IF) stages that could cause clipping and audio distortion.

When a receiver is used in radio astronomy applications, such as measuring solar radio bursts and Jupiter radio emissions, the audio volume limiting function of the AGC is not desirable because it could lead to inaccurate measurements. Therefore, the AGC functions in receivers used for this purpose are disabled. Some receivers have a user control for turning off the AGC; however, the 1254 has no such control and it is necessary to modify the AGC circuit.

Part of the AGC circuit in the 1254 includes a variable attenuator between the RF input and the first mixer, which limits the amplitude of incoming RF signals [TT1254]. The variable attenuator uses two PIN (positive-intrinsic-negative) diodes in a shunt-series arrangement. At radio frequencies, a PIN diode acts like a voltage controlled variable resistance. The bias voltage comes from the AGC circuitry comprised of Q9, Q10 and Q11 (figure 4). The AGC circuit continuously monitors the input signal level and adjusts the RF attenuator, thus keeping the audio volume relatively constant. The receiver also has an AGC line to the two IF amplifier stages, which use the MC1350 IF amplifier integrated circuit, but it takes effect only with very strong RF inputs.

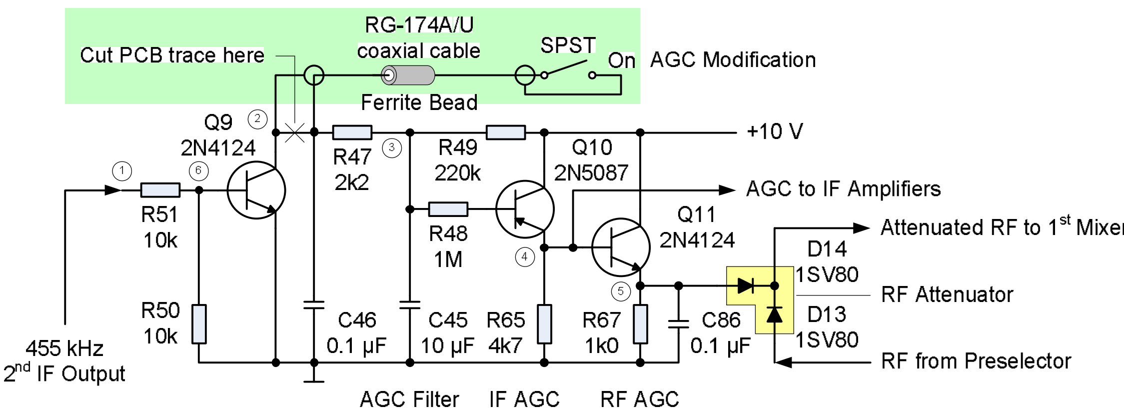
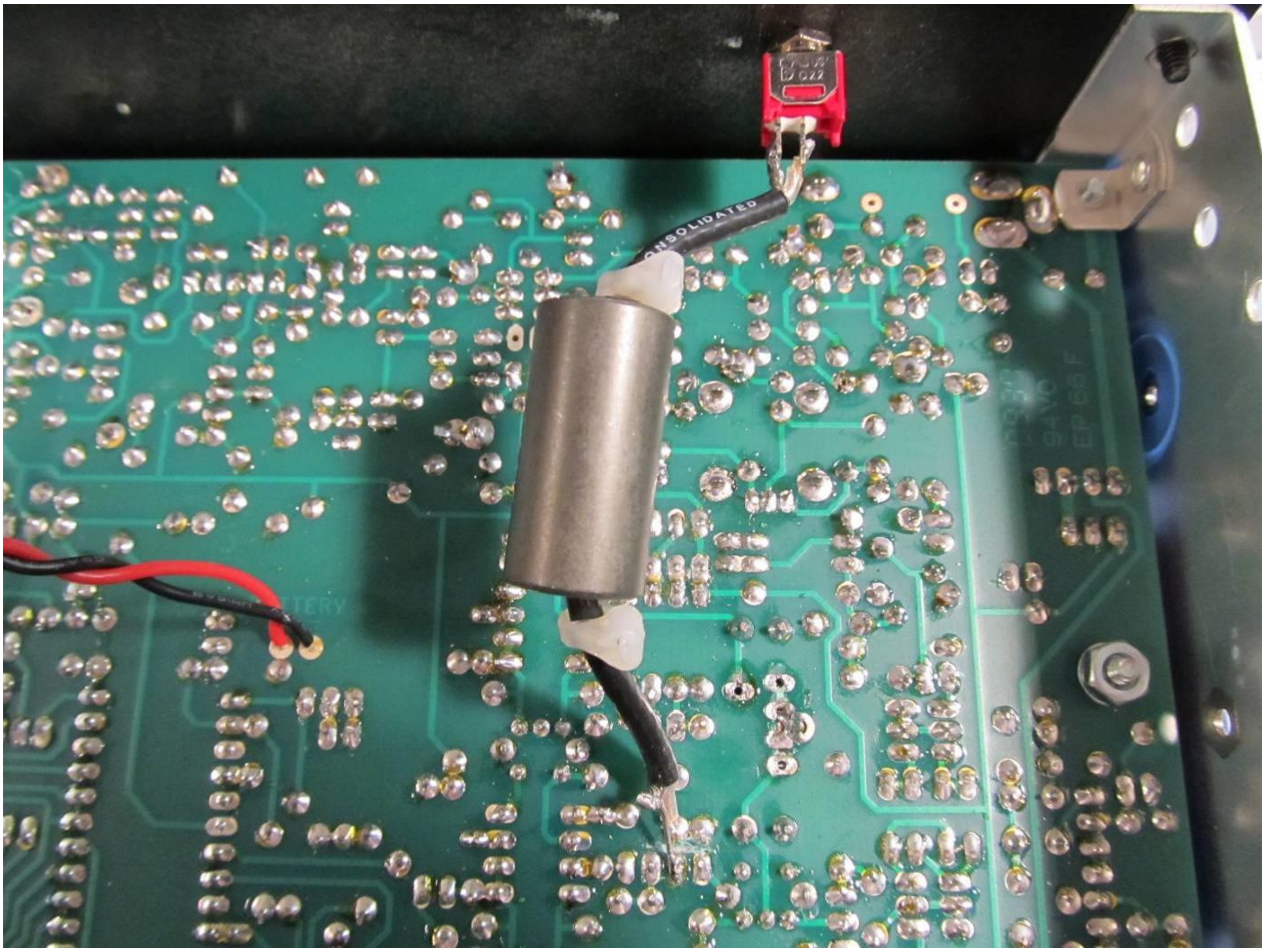


Figure 4 ~ Receiver AGC circuitry consisting of Q9, Q10 and Q11. In normal (unmodified) operation Q9 rectifies the IF and C46 filters out any residual 455 kHz components. C45 and R48 provide fast attack and slow decay so that strong signals do not result in a loud burst of audio. Modifications are shown in the shaded area at top. The small circled numbers are reference points for measurements of the AGC circuit.

In the 1254, the AGC circuit introduces no attenuation when the RF input circuits are not receiving a signal. I found by experimentation that the RF attenuator diode bias voltage does not change until the RF input signal reaches approximately –86 dBm (equivalent input noise temperature of around 182 million kelvin). Thus, the receiver operates at maximum RF gain at inputs below this level. It may be noted that an equivalent noise temperature of 182 million kelvin would represent a very powerful solar or Jupiter radio burst. One can conclude that an unmodified receiver could be used to measure Jupiter radio storms and most solar radio bursts, and I believe that would be a correct conclusion for my receiver. However, there may be variations among other kit-built receivers that would make this modification necessary.

4. Modification

The AGC modification described here is such that, when the AGC is turned off, the receiver is operated at maximum gain. The AGC modifications can be made after the receiver has been built. It is only necessary to cut one printed circuit board (PCB) trace to remove the collector of the AGC control transistor Q9 from the junction of R47 and C46 and install a short coaxial jumper (RG-174A/U) between the PCB and a new single-pole, single-throw (SPST) toggle switch (figure 2). A round cable ferrite bead is placed on the cable to reduce the possibility of interference being picked up by the cable and coupled into the receiver. The switch is used to turn the AGC on or off, allowing the receiver to be used for both radio astronomy observations (AGC off) and normal shortwave listening (AGC on).



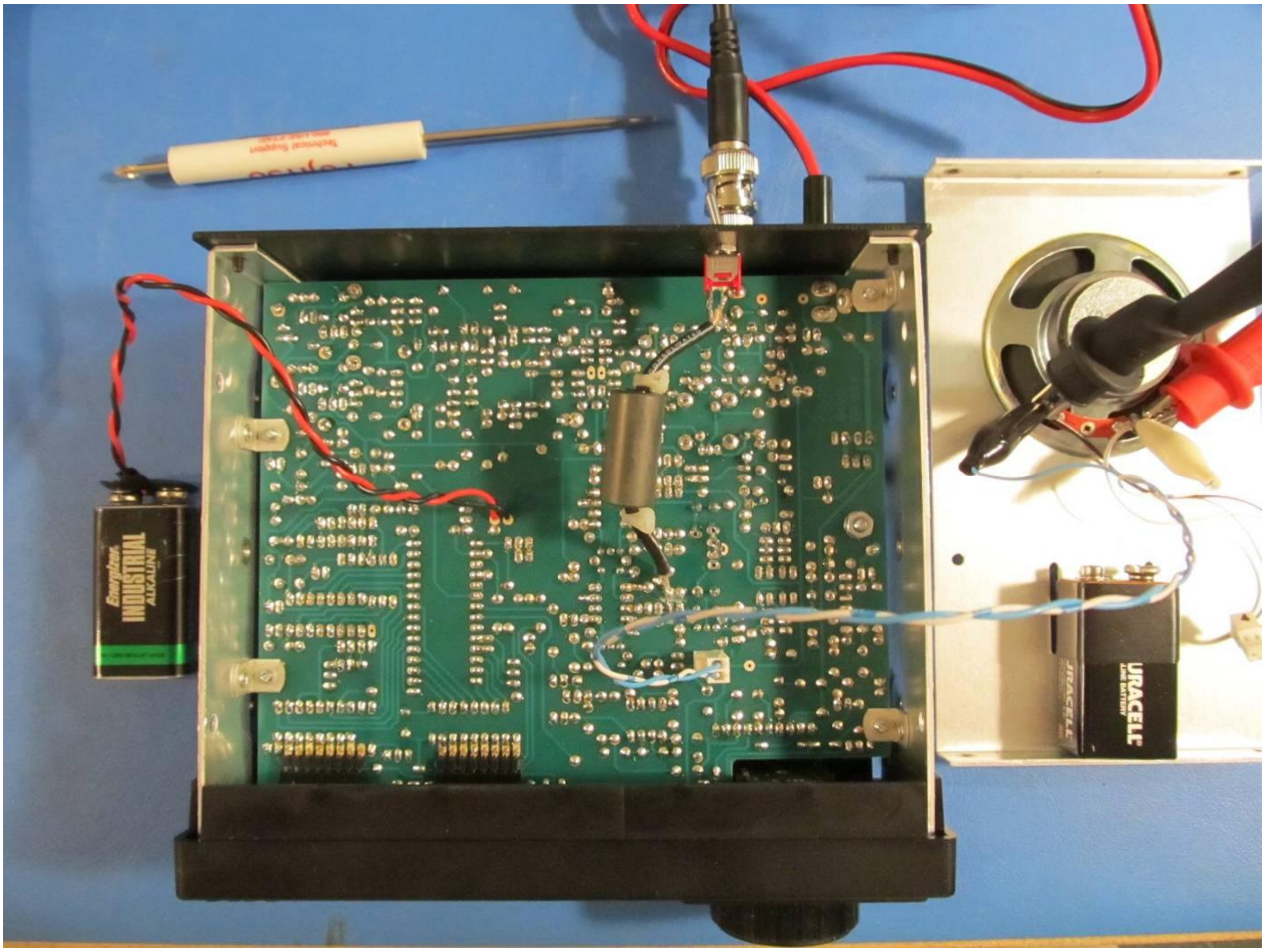


Figure 2 ~ Completed installation of coaxial jumper and toggle switch. Upper – Close-up showing coaxial jumper, ferrite bead and toggle switch; Middle – Full view of receiver bottom and speaker (right) and battery for frequency memory (left). The PCB is mounted upside down in the receiver's built-up frame chassis; Lower – Rear panel showing location of AGC On/Off switch. The switch location is not critical, the one shown is 45 mm from the left edge (as viewed from the rear) and 13 mm below the top. A BNC-F/RCA-M coaxial adapter is plugged into the Antenna socket.

Referring to the schematic and PCB layout (figure 3), after cutting the PCB trace the coaxial center conductor is soldered to the junction of R47/C46 and the shield is soldered to the collector of Q9. The cable is run to the toggle switch mounted on the rear panel and connected such that when the switch is in the AGC Off position, the circuit is open and when in the AGC On position, the circuit is closed.

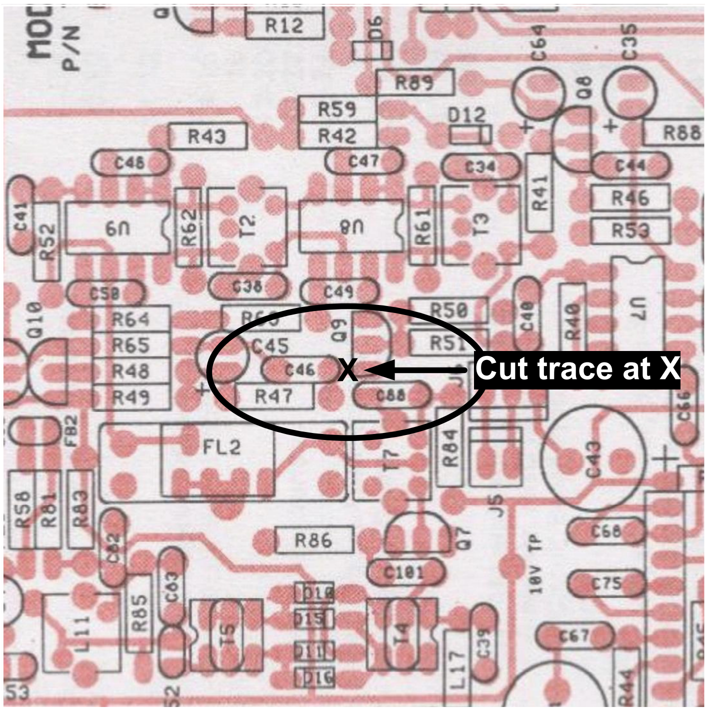


Figure 3 ~ X-ray view of printed circuit board layout in area of modification. The oval marks the location of R47, C46 and Q9 as seen from the PCB top. The PCB is cut on the bottom between the junction of R47 and C46 and the collector of Q9 and a short length of small coaxial cable is soldered as described in the text.

5. AGC measurements

As seen in the AGC circuit schematic, the AGC control voltage is applied to the RF and IF amplifier stages by R67 and R65, respectively. I measured the voltage at these two resistors and plotted them to show how the voltages change as the input signal level from an RF signal generator changes (figure 5). The IF amplifier integrated circuits do not respond to an AGC voltage less than 5 V, so their gain is reduced only for very strong input signals not seen on this chart. I also measured the receiver audio output for a 30 dB range of input noise temperatures from 23 200 to 23 200 000 K with the AGC on and off (figure 6).

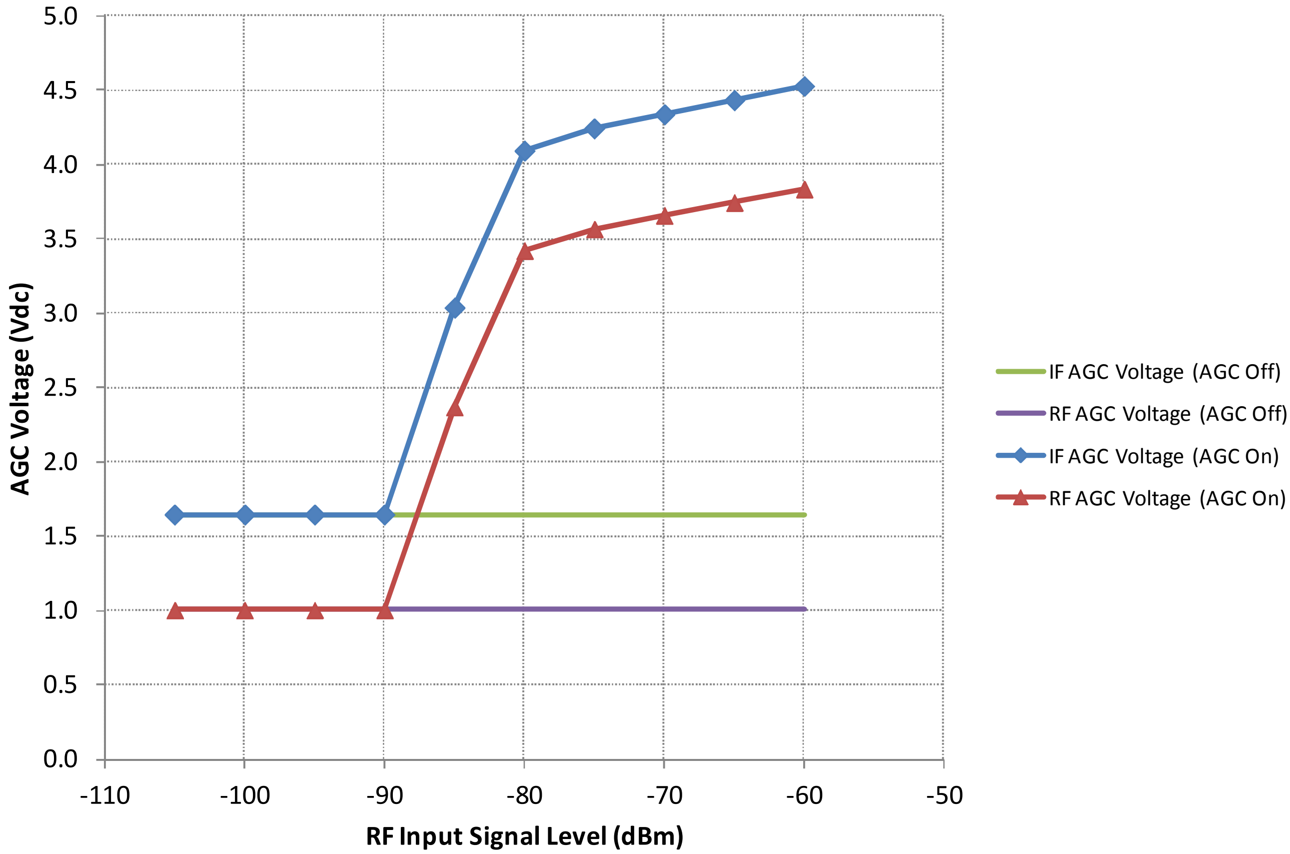


Figure 5 ~ AGC voltage at R67 and R65 (see schematic) as a function of RF input signal level with the AGC on and off. With the AGC turned On, the AGC voltage has a very sharp knee at about -86 dBm and increases rapidly as the input increases. A second knee appears at about -80 dBm. With the AGC turned Off, the AGC voltage remains constant. The measurements were made at 20 MHz.

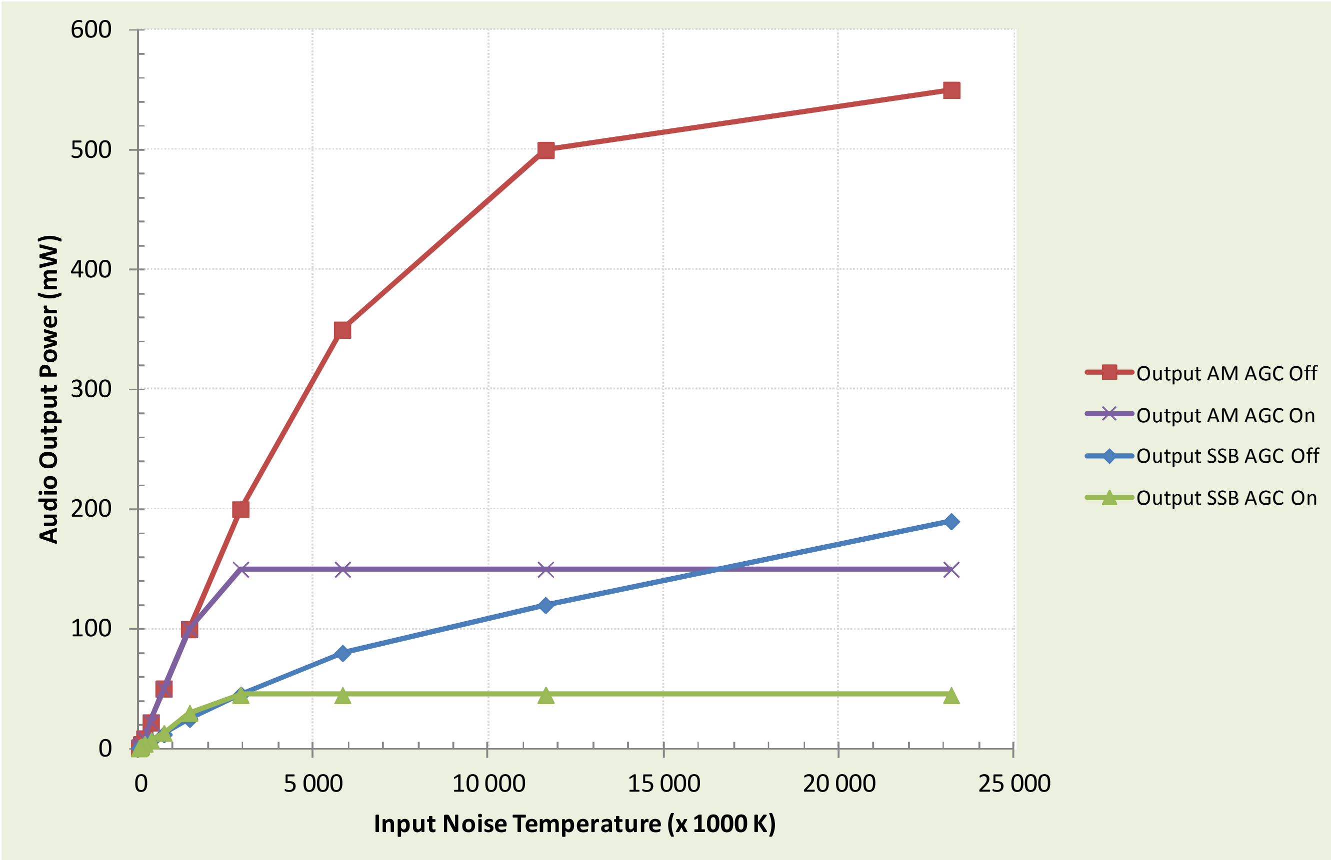


Figure 6 ~ Audio output power over a 30 dB range of input noise temperatures with AGC turned On and Off for AM and SSB modes. With AGC On, the receiver output changes approximately in proportion to the input until a noise temperature of about 3 000 000 K where it levels out. With AGC Off, the output continues to increase. In AM mode, the receiver saturates at high input/output powers. The measurements were made at 20 MHz.

6. Radio-SkyPipe calibration

For testing purposes, I ran Radio-SkyPipe calibrations for noise temperatures up to about 1.5 million kelvin (figure 7). These lower levels are suitable for Jupiter radio emissions. I also ran calibrations for temperatures up to 23.2 million kelvin (figure 8). These higher temperatures are suitable for solar radio bursts. The calibrations indicate that the modified receiver would be suitable for reasonably good measurements of Jupiter and solar radio emissions.

All measurements in this section were made at 20.1 MHz with the AGC turned off and the audio Volume control set to the 4th scale dot (of 10 scale dots). The Line In amplitude on the PC soundcard was set to 22%. Radio-SkyPipe was set to a sample rate of 10 samples/second, and the soundcard was set to 12 000 Hz sample rate with 16 bit resolution in Stereo mode. An RF Associates HOT-1 noise source was used with a 50 dB step attenuator to adjust the noise power level (The HOT-1 noise source is described in [Reeve]).

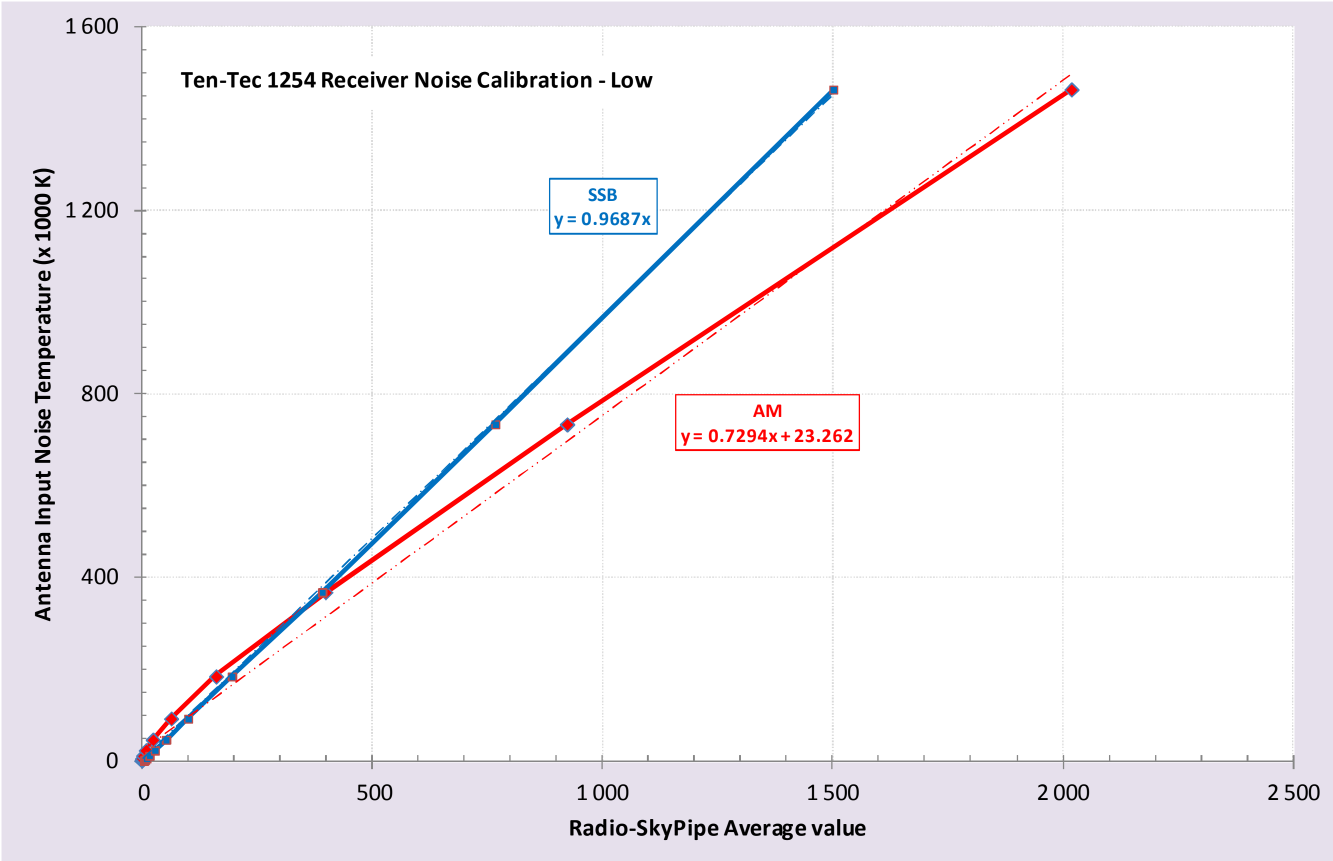


Figure 7 ~ Calibration curves for low level inputs such as Jupiter radio emissions. The solid lines show measured values and the dotted-dashed lines show linear trendlines. The receiver response is quite linear in the range shown especially when it is in the SSB mode.

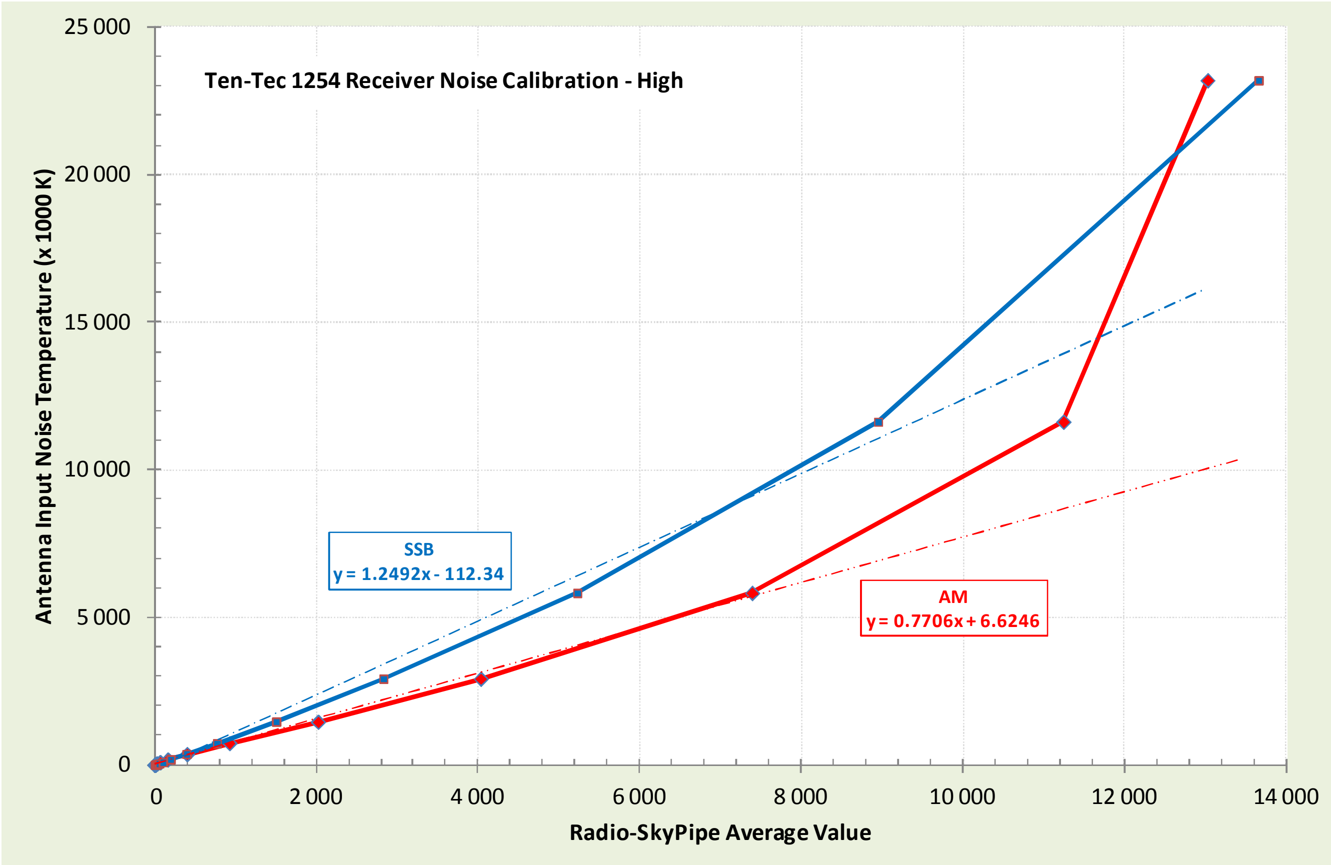
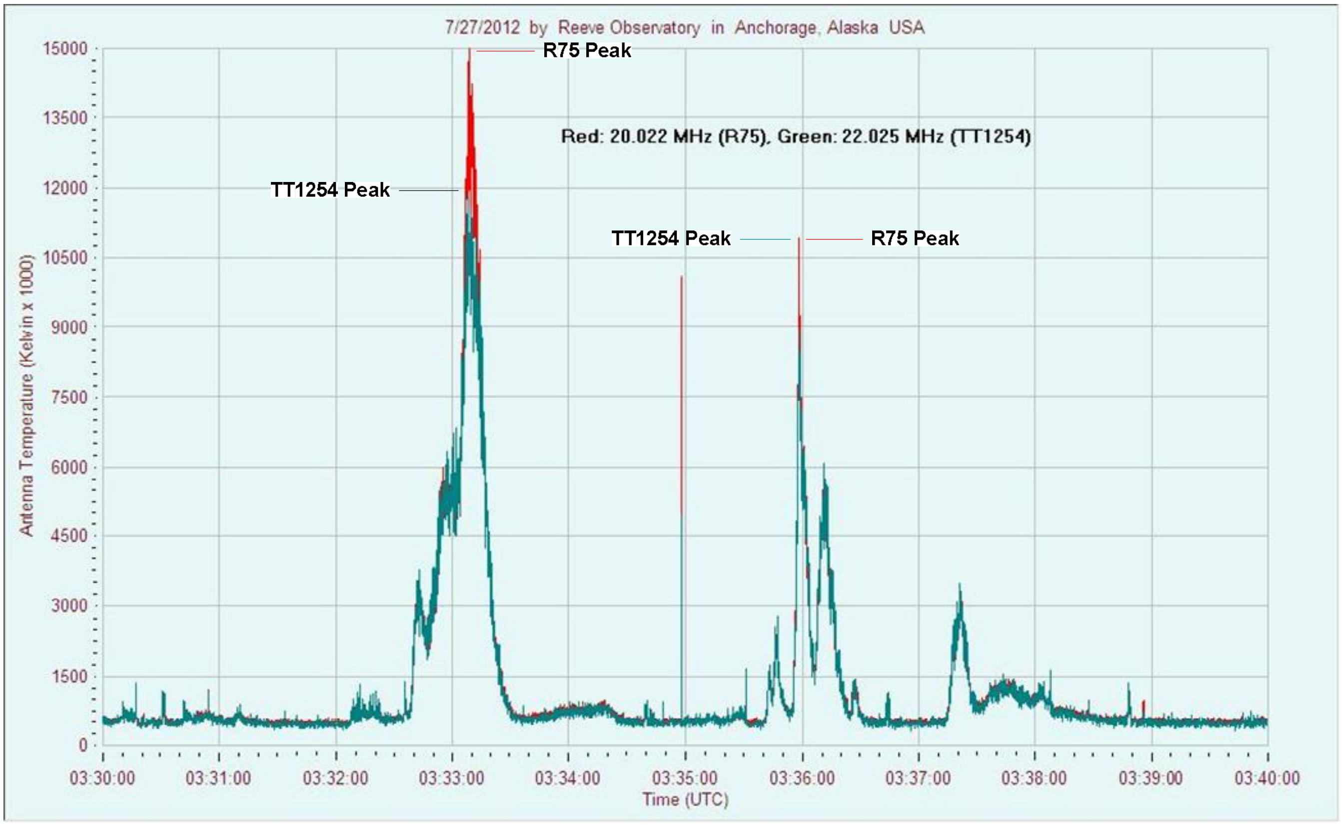


Figure 8 ~ Calibration curves for high level inputs such as solar radio emissions. The solid lines show measured values and the dotted-dashed lines show the linear trendlines. The trendlines do not use the last data point in SSB mode and the last two data points in AM mode. The SSB mode provides a slightly more linear response at high input noise temperatures than the AM mode. At a Radio-SkyPipe value of 12 000 the difference between the measured values and the trendline in SSB mode is about 1 dB and in AM mode is about 2.8 dB.

7. Comparison of solar radio bursts received with the 1254 with the R-75 receivers

In addition to the previous measurements made with a noise source, the 1254's response range was measured by comparing the Radio-SkyPipe traces of live solar radio bursts measured by the modified 1254 and a benchmark R-75 receiver (figure 9). The AGC was off in both receivers and Radio-SkyPipe was set to a sample rate of 10 samples/second. The soundcard was set to 12 000 Hz sample rate with 16 bit resolution in Stereo mode. The receivers were connected to the same antenna through a multicoupler.

These measurements show that the 1254 tracks the R-75 quite well up to about 10~12 million kelvin but above that the 1254 output trace drops below the R-75 trace. For lower-level bursts, the two traces are indistinguishable, thus confirming the lab measurements with a noise source.


7/27/2012 by Reeve Observatory in Anchorage, Alaska USA
R75 Peak
Red: 20.022 MHz (R75), Green: 22.025 MHz (TT1254)
TT1254 Peak
TT1254 Peak
R75 Peak
Antenna Temperature (Kelvin x 1000)
15000
13500
12000
10500
9000
7500
6000
4500
3000
1500
0
03:30:00
03:31:00
03:32:00
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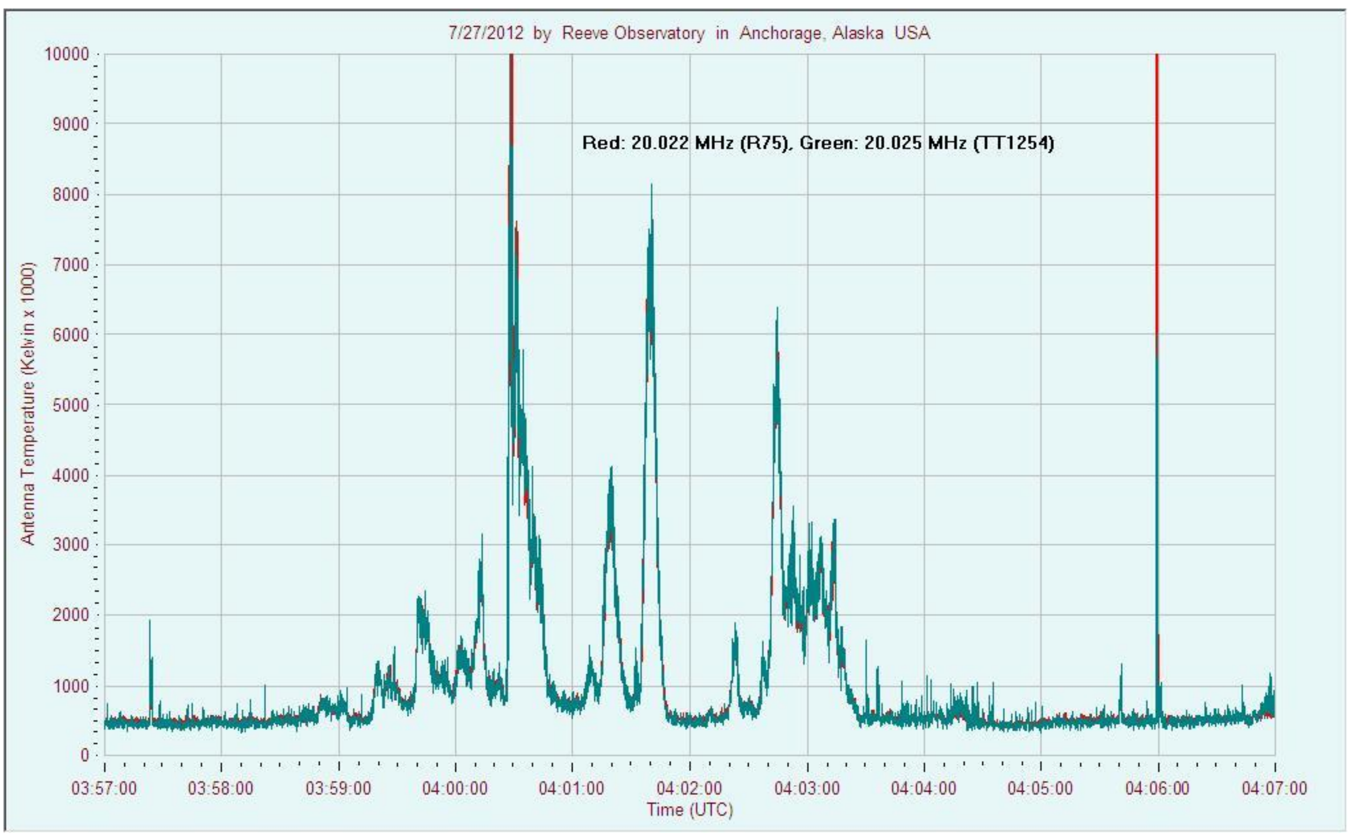
03:40:00
Time (UTC)


7/27/2012 by Reeve Observatory in Anchorage, Alaska USA
Red: 20.022 MHz (R75), Green: 20.025 MHz (TT1254)
Antenna Temperature (Kelvin x 1000)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
03:57:00
03:58:00
03:59:00
04:00:00
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04:07:00
Time (UTC)

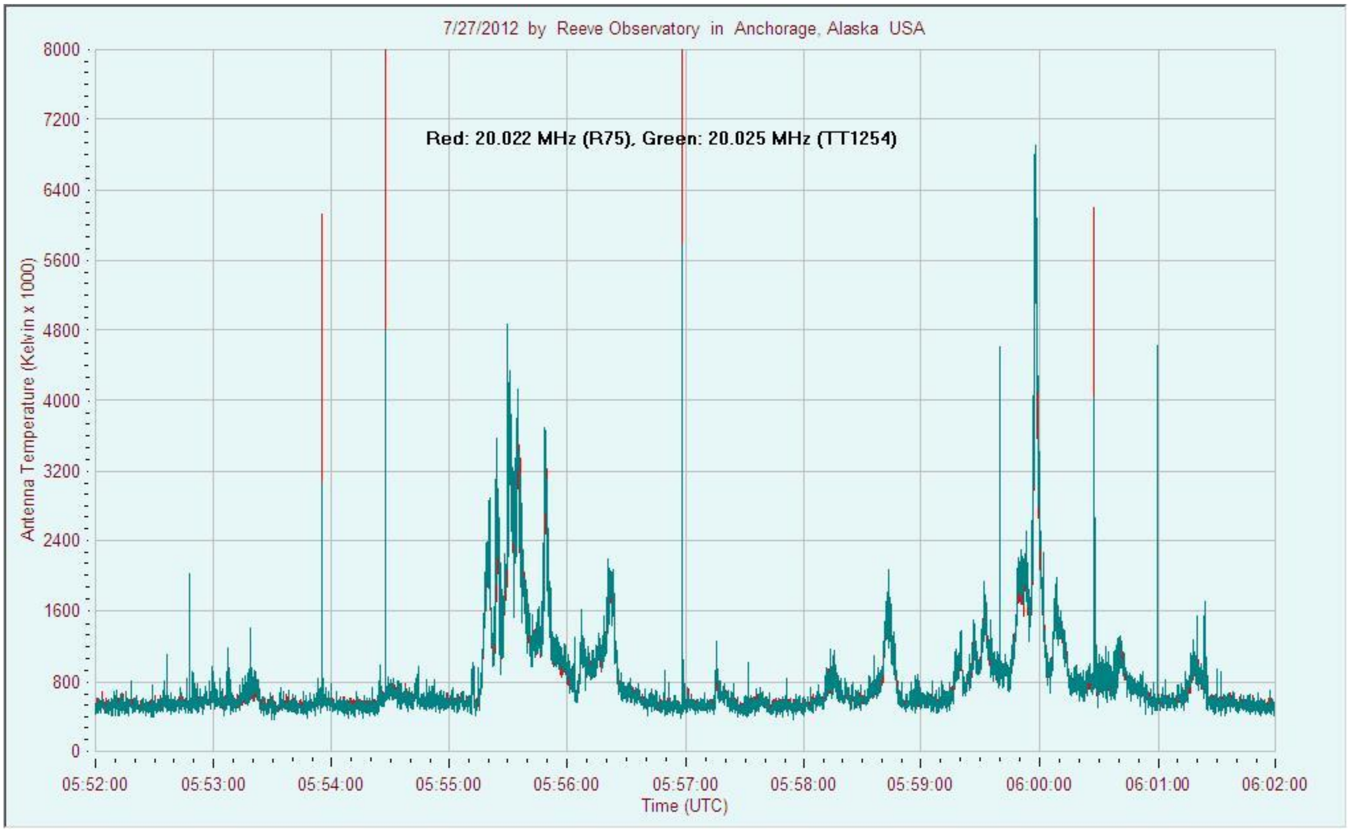

Figure 7 ~ Radio-SkyPipe charts showing several solar bursts on 27 July 2012 for comparing the R-75 output (red trace) with the 1254 output (green trace) at frequencies indicated. The top chart is annotated to show the peak burst temperature measured by the two receivers. It is seen that the 1254 tracks the R-75 very closely until the burst noise temperature reaches about 12 million kelvin above which the 1254 output starts to drop off. The middle and bottom chart show that for moderate burst strengths, the two traces are indistinguishable.

8. Discussion

The background noise temperature at 20 MHz is around 50 000 K (for example, see references [ITU-R 508] and [ITU-R 720-2]). The background noise represents the limit below which amateur radio astronomers cannot receive celestial emissions. Therefore, we can assume the minimum RF input noise temperature for measurement purposes is 50 000 K and then determine the range above it that the receiver will track. For this situation, the 1254 tracks the R-75 receiver over a range calculated as follows:

Range above background =
  10* log (Maximum noise temperature for linear tracking / Background noise temperature)

where
  Maximum noise temperature for linear tracking = 12 000 000 K
  Background noise = 50 000 K

Substituting these values we find

  Range above background ≈ 24 dB

Solar bursts can rise 40 dB or more above the background noise, so the 1254 may not be suitable for accurately measuring very powerful solar bursts. However, it may be suitable for measuring Jupiter emissions, which rarely rise 10~12 dB above the background noise when received by a low-gain antenna. I have received Jupiter emissions exceeding the background noise by over 20 dB with a log periodic antenna. A 10 dB rise would be equivalent to an antenna noise temperature of 500 000 K and 20 dB would be 5 000 000 K, well within the modified receiver's capabilities (and even within an unmodified receiver's capabilities). It should be noted that much stronger Jupiter radio bursts can be measured with high-gain antennas.

9. Future work

Future work includes replacement of the microprocessor with later technology, which allows finer frequency tuning control and provides more frequency memory, and the installation of an EIA-232 serial port for software control of the receiver. In addition to these benefits, the new microprocessor turns off the LED frequency display after a preset time delay and reduces the receiver's internally generated noise. Such a modification, or upgrade, is commercially available and will be described in another article.

10. Conclusions

The Ten-Tec 1254 receiver is easily modified so that the automatic gain control can be turned on or off. It may be used for receiving radio emissions from the Sun and Jupiter and has the best response when used in the SSB mode.

Some nice features of the 1254 are that it is sensitive and not very expensive, can be built and modified by the user and, after modification, also can be used for its original intended purpose as a general coverage shortwave listening receiver.

11. References

[ITU-R 508] ITU-R Recommendation 508, Use of Radio-Noise Data in Spectrum Utilization Studies, International Telecommunications Union – Radiocommunications Sector, 1978 (Note: ITU-R documents can be downloaded here: http://www.itu.int/en/publications/Pages/default.aspx)

[ITU-R 720-2] ITU-R Report 720-2, Radio Emission from Natural Sources in the Frequency Range Above About 50 MHz, International Telecommunications Union – Radiocommunications Sector, 1986

[Reeve] Reeve, W., Packaging the HOT-1 Noise Source, Radio Astronomy, October 2012

[TT1254] Ten-Tec 1254 Kit Assembly and Instruction Manual, KIT Manual No. 74477, July 2012

12. Appendix – Ten-Tec 1254 Specifications (unmodified)

Parameter	Specification	Remarks
Original purpose	Shortwave listening (SWL)	
Frequency range	100 kHz to 30 MHz	
Tuning steps	2.5 kHz (SSB), 5.0 kHz (AM)	
Frequency control	Microprocessor controlled frequency synthesizer	Microchip PIC16C57
Frequency control method	Manual	
Frequency display	7-segment LED (green)	
1st IF	45 MHz	
2nd IF	455 kHz	
Bandwidth	4 kHz at –6 dB (determined by 2nd IF filter)	1 kHz in test receiver
RF sensitivity	2.5 μV (AM), 0.5 μV (SSB) for 10 dB SNR	Not verified
RF input	Unbalanced (RCA phono jack)	Impedance not specified
Audio output power	1.5 W	
Audio output	Built-in speaker + 4~8 ohm output (3.5 mm mono jack)	
Frequency memory	15 storage locations	
Power requirements	12~15 Vdc, 260 mA	Current at low audio volume
Dimensions	165 mm wide x 165 mm deep x 57 mm high	
Weight	1 kg	Not including ac adapter
PCB components	Through-hole (no SMD)	
Construction difficulty	Intermediate	