30-line television by medium-wave radio: the GNU Radio flowgraphs

12 November 2026. This is the setup for the Baird experiment. The PC and HackRF send a 30-line picture as an ordinary AM medium-wave signal, the way the BBC sent Baird's pictures. A real 1920s receiver picks it up, and the 30-line box turns the receiver's output into a picture on the 1200B. The televisor will be fed the same way once it's built.

Status: both flowgraphs pass GNU Radio's own checks. The simulation has been run, and decodes 12.5 pictures a second. The signal path is tested offline at receiver bandwidths from 12 kHz down to 3 kHz (section 6). Not yet tried with the HackRF and a real receiver.

1 The idea

Stage	What it does
WAV file	The 30-line test card as sound: 48 kHz, 128 samples a line, sync pulses at the lowest level
Video low-pass	Sets how much picture detail is sent. The default 4.5 kHz fills a 9 kHz channel, the bandwidth the BBC used (Newnes Complete Wireless). 13 kHz sends all the card's detail
AM	1 + m × picture: sync tips are the lowest carrier, peak white the highest, as Baird did it
HackRF	Sends it on a medium-wave frequency between 1.0 and 1.7 MHz, by cable into the receiver's aerial terminal
1920s receiver	Tune it in like any station. Its detector and audio stages give back the picture signal as sound
Pick-off (figure 1)	Takes that signal safely off the loudspeaker terminals
30-line box	AUDIO IN, then the box draws the picture on the 1200B

A radio has one output, so only the picture channel can come through it. The stereo WAVs carry the line-1 marker (a pulse 4 times longer) on the right channel. `make_30line_mono.py` copies it into the picture channel, so a single radio channel still carries it.

2 The files

All of these are in `Pi_Signal_Generator\hackrf\gnuradio_30line`.

File	What it is
`run_tv30_sim.bat`	**Start here.** The simulation: no HackRF needed
`run_tv30_tx.bat`	Transmits on medium wave with the HackRF
`open_tv30_in_grc.bat`	Opens both flowgraphs in GNU Radio Companion
`tv30_tx.grc` / `tv30_sim.grc`	The flowgraphs. `tv30_tx.py` and `tv30_sim.py` are made from them
`picture30_block.py`	The 30-line picture window: decodes the signal like the box
`Project405_30line_card_mono.wav`	The test card as a mono signal with the line-1 marker
`make_30line_mono.py`	Makes that mono WAV from any stereo 30-line WAV
`make_grc30.py`	Writes both flowgraphs. Run it after changing anything
`test_chain30.py`	The offline test (section 6)

It uses the same GNU Radio 3.8 installation as the 405-line transmitter.

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3 First, without the radio: `run_tv30_sim.bat`

This sends the signal through a pretend 1920s receiver and shows what comes out. Two picture windows open, "as sent" and "received", with two scope traces of 2 lines each.

Control	Use
Noise	Raise it to see a weak or distant signal
Video bandwidth	How much detail is sent: 4.5 kHz as the BBC (the default), up to 13 kHz
Receiver bandwidth	1920s sets are perhaps 3–5 kHz. Below about 3 kHz the picture smears and sync starts to go
Polarity	Flips the transmitted signal (section 5)
Receiver output polarity	Pretends the set turns the signal upside down. Fix it with Polarity
Sound card level	The received signal also goes out of the PC's headphone socket

To try the 30-line box with no radio at all, plug the PC's headphone socket into the box's AUDIO IN and press SOURCE twice. Start with the PC volume low.

4 With the HackRF and the 1920s receiver: `run_tv30_tx.bat`

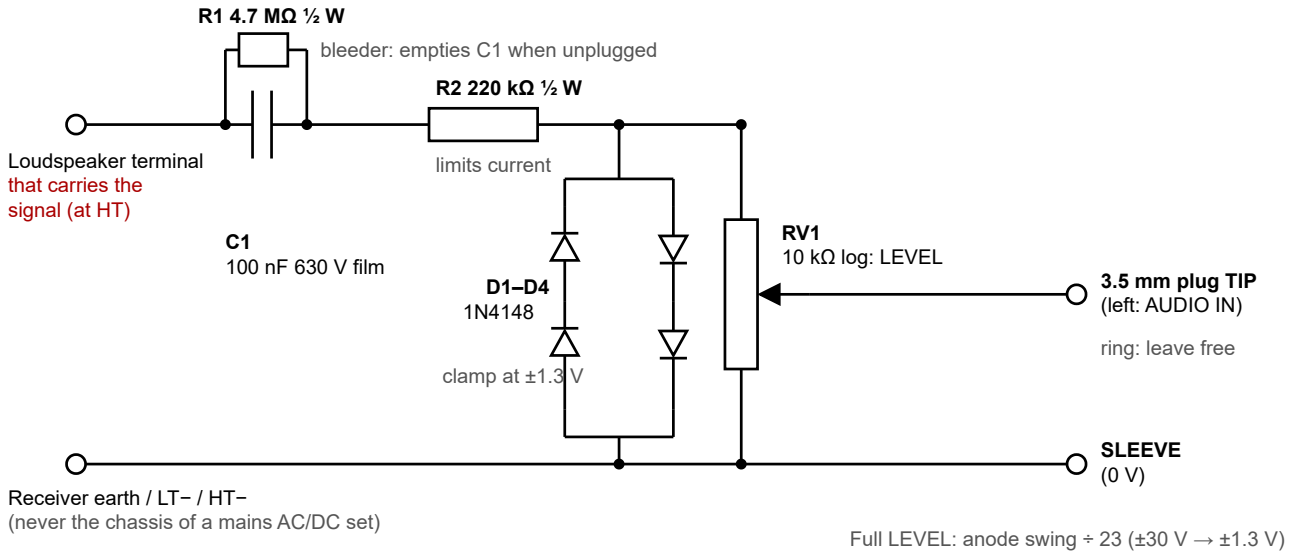
1. **By cable, not over the air.** The HackRF's SMA output goes through a 20 dB attenuator to coax, then to the receiver's aerial and earth terminals. Radiating on medium wave needs a licence. A cable also keeps the HackRF's harmonics (2.4, 3.6 MHz…) out of everyone else's radio.
2. **Pick a frequency** that the set tunes and where there's no station, for example 1.2 MHz (250 m). The HackRF works from 1 MHz, so 1.0–1.7 MHz (300–176 m) covers most of the 1920s medium-wave band, but not long wave. The slider also covers the command receivers, 0.19–9.1 MHz (section 5a).
3. **Start at TX gain 0.** Tune the set to the carrier: the speaker gives a harsh 375 Hz buzz. Raise the gain until the buzz is strong and clean, but not so far that it flattens. An overloaded detector squashes the whites.
4. **Reaction:** keep it well below oscillation. Close to oscillation, the set's tuning gets very sharp and cuts the picture detail. Into oscillation, a whistle ruins it.
5. Connect the pick-off (section 5) to the box's AUDIO IN, press SOURCE twice, and set the LEVEL.

5 Getting the signal out of the receiver

The problem. In most 1920s sets, the loudspeaker or headphones are in the anode circuit of the output valve. One terminal goes to HT+ and the other to the anode. So both terminals sit at the full HT, perhaps 60–150 V from an HT battery, and the signal swings tens of volts around it at high impedance. The box's input wants no DC at all, and no more than about ±1.6 V.

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Figure 1: taking the 30-line signal off a 1920s receiver (battery set)



The pick-off (figure 1). It can be built on a scrap of tagboard in a small box:

- **C1** (100 nF, **630 V** film) blocks the HT and passes the signal.
- **R1** (4.7 MΩ, across C1) empties C1 when you unplug it, so the plug can't give you a jolt.
- **R2** (220 kΩ) and **RV1** (10 kΩ log pot) divide the signal down: by 23 at full LEVEL, so ±30 V becomes ±1.3 V. R2 also limits the current to under 1 mA, even at the moment you connect and C1 charges to the HT. Use ½ W resistors, which are rated for the voltage.
- **D1–D4** (1N4148, two in series each way) clamp the output at about ±1.3 V, inside what the Pico can take.
- The output goes to a 3.5 mm plug: **tip** = signal (the box reads the left channel), **sleeve** = 0 V. Leave the ring free, or use a mono plug.
- The **0 V lead** goes to the receiver's earth terminal (LT−/HT−), never to the other loudspeaker terminal.

Which loudspeaker terminal? Use the anode side: the one that carries the signal. On many sets it's the terminal marked −, while + goes to HT+. If they aren't marked, measure AC volts on each to earth with the buzz playing. The anode side shows several volts, and the HT+ side almost nothing.

Leave the loudspeaker connected. The output valve's anode current flows through it. For silence, fit a resistor in its place: about 2.2 kΩ 3 W, or the speaker's own DC resistance. A pair of high-resistance headphones also works.

Mains sets. Some late-1920s sets run from the mains, and AC/DC sets have a live chassis. For these, the pick-off must have an **isolating audio transformer**: one with a 10 kΩ or higher primary, rated for the HT, fed through C1. Its secondary goes to RV1 and the diodes. Never connect the box's 0 V to the chassis of a mains set. Battery sets (and sets on a battery eliminator, whose HT− is earthed) are fine with figure 1 as drawn.

Setting the level: start with LEVEL at minimum and turn it up until the picture is steady. The SYNC LED lights when the box locks.

5a The command receivers

The carrier slider covers 0.19–9.1 MHz, so the same transmitter works for the command sets as well as the 1920s set.

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Set	Band	IF	Try	Keep clear of (IF harmonics)	Picture?
BC-453	190–550 kHz	85 kHz	300 kHz or 380 kHz	255, 340, 425, 510 kHz	Probably too narrow (below)
R-25 (ARC-5)	1.5–3.0 MHz	705 kHz	2.0 MHz	2.115, 2.82 MHz	Should be good
BC-454	3–6 MHz	1415 kHz	3.5 or 5.0 MHz	4.245, 5.66 MHz	Should be good
BC-455	6–9.1 MHz	2830 kHz	7.0 MHz	8.49 MHz	Should be good

- **The BC-453's band is below the HackRF's rated 1 MHz.** For carriers under 0.9 MHz, the flowgraph keeps the HackRF tuned at 1.1 MHz, inside its range, and shifts the signal down digitally (up to 0.91 MHz). The HackRF's output gets weaker below 1 MHz, but these sets need only microvolts. Start at full TX gain with less attenuation, and back off if it overloads. Not yet tried.
- **The BC-453's 85 kHz IF is the narrowest of the lot.** That's why it was famous as a "Q5-er" for selectivity. In the simulation, a receiver passing 2.5 kHz still gives a soft but recognisable picture. At 2 kHz and below, the sync pulses smear away and nothing locks: the 167 µs sync pulse needs about 3 kHz. Whether the BC-453 gets a picture depends on its real bandwidth, so try it last.
- **MCW, not CW:** the beat oscillator must be off, or it beats with the carrier. On the bench unit that's S3 at MCW.
- **Volume:** these sets have no audio volume control. The bench unit's gain control (RF and IF gain) sets the level. Turn it down if the whites flatten, because the detector is overloading.
- **No AVC,** which suits a picture signal: there's nothing to make the brightness pump.
- **Taking the signal off is easier than on a 1920s set.** The audio leaves through the set's own output transformer, so there's **no HT on the telephone line**.
    - From the bench unit's **JK2** (the 8 Ω low-impedance phones jack on T2): a 1 kΩ pot across it, with the wiper to the box's tip and the sleeve to 0 V, is enough. Add the two pairs of 1N4148 clamps across the pot for safety.
    - From **JK1** (the 8000 Ω phones line), the signal is about 30 times bigger. Use figure 1 as drawn; C1 is then just a precaution.
- **Check by eye first** in `run_tv30_sim.bat`: set Receiver bandwidth to what you expect the set to pass (perhaps 3–4 kHz for the voice sets).

6 Polarity, line 1, and what was tested

Polarity. Each valve stage turns the signal upside down, and transformers can be wired either way. So a set may hand back the picture as a negative, with the sync pulses at the top. The box can't lock to that. If the picture won't lock, or looks negative, flip **Polarity** on the transmitter.

Line 1. The current firmware looks for the line-1 marker on the right channel only. On a single radio channel it locks the lines but may start the picture part way across. Press **FRAME** until it's square, as the firmware notes describe.

Tested offline (`test_chain30.py`, with GNU Radio's own blocks, 3 seconds per case):

Receiver	Pictures decoded	Match to the original picture
Wide (12 kHz), full detail sent	36	0.96
1920s set, 5 kHz	36	0.90
BBC 9 kHz channel (4.5 kHz video), 5 kHz set: the default	36	0.89

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1920s set, 3 kHz	36	0.85 (soft, but all there)
3 kHz with noise	36	0.84
Set turns it upside down	0	no picture, as expected
The same, fixed with Polarity	37	0.90

For the box, through a real receiver. Making the picture window cope with narrow, noisy receivers took three things a television also has:

- **A sync-tip clamp.** The coupling transformers make the level wander from line to line.
- **Flywheel sync.** Once locked, it only looks for a pulse where the next one is due, so dark picture detail at sync level can't break the lock.
- **Finding line 1 by score.** Over the last few pictures, it keeps a score for each of the 30 positions: how far the signal stays below black just after the pulse. The long pulse wins every time, so it works like an automatic FRAME button, and a line that starts black can't fool it.

The 30-line box's firmware has none of these yet, and it reads the line-1 marker from the right channel only. On a good signal it should lock as it is. Through a narrow 1920s set it may drop lines, or need FRAME pressed. The same three changes can go into the firmware once the first real test shows how the set behaves.

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