Vintage Radio Alignment:
What It Is and How to Do It

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Vibrations

A musical instrument’s string has a fundamental frequency at which it will naturally vibrate.

- This frequency depends on three things:
  - Length of string
  - Tension on the string
  - Mass of the string

- Change any of the above and you change the fundamental frequency at which the string will naturally vibrate.
Vibrations

- **HOW** do I get the string to vibrate?
  - Through physical contact
    - Plucking
    - Strumming
    - Bowing
  - Through *Resonance*
What’s Resonance?

- Resonance occurs when the vibration in one vibrating system stimulates a vibration in another system.

- For example: Singing into my guitar will make the strings vibrate, even if I do not physically touch them!

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Power Transfer

- Resonance is a form of *Power Transfer*.
- I’m *transferring* the acoustic energy of my voice to the guitar string.
- I can make the guitar strings vibrate to some degree no matter what frequency I sing into it.

*However*, I’ll get:

1. More vibration in the string if I sing a note that is close to the string’s natural frequency.
2. Less vibration in the string if I sing a note that is different than the string’s natural frequency.

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Power Transfer

- To transfer the *maximum* amount of power from my voice to the guitar string:
  - I must sing the *exact* frequency of the string’s natural vibration
    -- *or vice versa* --
  - The string must be tuned *precisely* to the note I sing.

- If I change the note I sing, I will have to change the natural frequency of the string to get the same amount of power transfer.

- I can change the natural frequency of the string by:
  - Shortening the string
  - Tightening the string
  - Changing its mass
Do You See a Metaphor?

Resonant frequencies allow for the transfer of power from one source to another.

My Voice = An acoustic transmitter
Guitar String = An acoustic receiver

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The Metaphor Explained

- Just like a guitar string has a natural fundamental frequency, a wire antenna has a natural, fundamental frequency at which it is most sensitive to radio waves.

- Again, like a guitar string, the antenna’s length is one of the factors that determines the radio frequency at which it is most sensitive.

- Even though an antenna is most sensitive to a specific frequency, it will, to some extent, pass any and all radio frequencies, just like I can get a guitar sting to vibrate a tiny bit no matter what frequency I sing into it.

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What is the Fundamental Frequency of a Radio Antenna?

- An antenna most naturally vibrates to radio frequencies having a wavelength either two or four times the length of the antenna itself.

- Stated another way, an antenna is most sensitive if it is ¼ or ½ of the wavelength of the radio frequency that it is receiving or transmitting.

- *Wavelength* is another way to describe an oscillation.
  - *Frequency* describes *how often* something vibrates
  - *Wavelength* is the *distance between peaks* (typically in meters).

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How Long Are We Talking?

- WLS broadcasts on 890 KHz, a frequency that has a wavelength of 337 meters.

- So, to hear WLS, you’d need an antenna:
  - 168.5 meters long (1/2 wavelength)
  - or -
  - 84.25 meters long (1/4 wavelength)

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But That’s CRAZY

- You’re right! A football-field length antenna is way too long to use practically. *Plus…*
  - It’s woefully inadequate even if you could use it.
  - We’d need to change antennas every time we wanted to listen to a different station!

- Therefore, we need to devise a way to “adjust” the natural vibration of the antenna.
The Resonant Circuit

- A capacitor and an inductor in parallel create a “resonant circuit” (sometimes called an LC circuit).
- This circuit has a certain fundamental frequency at which it will “vibrate” (or oscillate).
- By varying the value of either the capacitor or the inductor, I can vary the natural, fundamental frequency of the resonant circuit.

L is the symbol for inductance
C is the symbol for capacitance

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Our Metaphor Again...

Just like a tuning knob on a guitar changes the tension of the string, causing the frequency of its natural vibration to change,

The tuning knob on the radio changes either the capacitance or the inductance of the resonant circuit, causing the natural resonance of the radio circuit to change.

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Radio broadcasting and reception is a similar process of power transfer as singing into my guitar.

The radio station emits a “vibration”

That vibration travels through space and can create a similar vibration in my antenna.

I get maximum power transfer from the transmitter into my radio if the antenna is tuned precisely to the frequency of the radio station.
RF Waves Are Weak

- Even if the receiver’s resonant circuit transfers maximum power into a radio, the signal (about 200 microvolts) isn’t strong enough to be heard through loudspeakers.

- Vacuum tubes increase the power of the vibrations, so that the audio frequencies embedded in the RF wave are powerful enough to be heard.

- However, one tube is usually not enough!

- The signal must be passed from one tube to another tube, typically through additional resonant circuits.
So What is Alignment?

- Just like *all* the strings of a guitar need to be tuned for the radio to sound its best, we must:

- Make sure *all* the resonant circuits are precisely tuned to allow maximum power transfer from transmitter to antenna, and from antenna to loudspeaker.

- But *how many* tuned circuits are in a radio?

- That depends on lots of things!

- But in general, the more tubes in a radio, the more tuned circuits there are.
Early TRF Sets

- Each stage is tuned independently of the others.
- You “align” the radio simply by tuning in a station!

AK Model 10B

The Atwater Kent “Model 10B,” a very early “breadboard” receiver. The circuit is quite simple, and the controls numerous. It is designed for storage-battery tubes, and has potentiometer R.F. control. It may be readily altered to use a power tube.
Problems with TRFs

- TRFs were unstable and difficult to operate.
- They howled, squealed, and *heterodyned* as each stage was tuned independently of the others.
- One early fix: Gang the tuning condensers to each other by:
  1. Using a chain or belt
  2. Putting all of them on one shaft.

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Since all tuning condensers are now adjusted simultaneously, we need some way to compensate for the imperfect “ganging” of each one.

Radio designers added a compensating or trimmer condenser to the resonant circuit, allowing each tuning condenser to be fine-tuned (or aligned) with the other.
Objective of Alignment

1. Transmit a consistent, steady, audio tone on a stable, known RF frequency into a radio receiver.

2. Adjust all compensating condensers so that each resonant circuit is precisely tuned to the known frequency.

3. Ascertain the degree of this tuning (or “alignment”) by measuring the AC voltage at the speaker.
Rules of Thumb

1. Avoid *loading the circuit* when connecting test gear.
   a. Induce the signal into the receiver.
   b. Measure the voltage at the speaker’s voice-coil.

2. Turn radio volume on full, and use as weak a signal from the generator as possible.

3. Know whether you are adjusting the *capacitance* or the *inductance* of the circuit.

4. Make the last motion a *tightening* one.

5. Begin at the speaker and work backward to the antenna.

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To Avoid the Loading Effect:

- Induce the test signal into the antenna
  1. Connect the positive and negative leads from the signal generator to the lugs on a spare loop antenna.
  2. Coil the radio’s wire antenna around the test loop.

  - or -

  If set uses a loop antenna, put both loops back-to-back.

- To measure AC voltage, clip the positive and negative leads to the secondary winding of the output transformer (the leads that go to the speaker voice-coil).

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Let’s Align a TRF

1936 Emerson 126
Note the compensating condensers in parallel with C-2 and C-3 above.
Single-Dial TRFs Sound O.K. But...

- Remember the term *heterodyning*, one of the big problems of the three-dial TRF?

- *Heterodyning* is what happens when two frequencies interfere with each other.
  - If the two frequencies are close, they “beat” against each other at a slow rate.
  - The farther apart they are, the faster they “beat” against each other.
  - This “beating” can be isolated, and thought of as a new frequency!

- Edwin Armstrong’s idea: Turn the heterodyning principle to an *advantage*: the Super-Heterodyne
How Does A Super-Het Work?

- It uses the principle of heterodyning to turn the frequency at the antenna, no matter what it is, into a new, fixed frequency.

- Then, all the other tuned circuits in the radio can be set to this one, fixed frequency, called the *Intermediate Frequency* (IF).

- We create the IF by *heterodyning* the antenna frequency with another radio frequency generated within the radio itself, by the *local oscillator*.

- In general, now, the only stage that has to be tuned is the antenna! Each subsequent amplification stage is pre-tuned to the IF and should rarely be adjusted.

- Makes for a much more stable, easy to operate, better sounding receiver

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The antenna frequency is amplified and mixed with local oscillator frequency in the 12SA7 tube.

Mixing these frequencies produces the Intermediate Frequency, 455 KHz in this case.

The IF is typically the difference of the antenna frequency and the oscillator frequency (AF – LO = IF)

As the antenna is tuned to other frequencies, the frequency generated by the LO also changes, so that the difference between the two is always 455 KHz.

The Intermediate Frequency Transformers (T1 and T2) are tuned to 455 KHz and pass the amplitude-modulated signal to the 12SK7 and 12SQ7 tubes for further amplification and rectification.
Another “All-American Five”

1939 Stewart Warner 07-5B “Senior Varsity”

- Note the compensating, “trimmer” condensers in parallel with both 21A and 21B on the antenna and oscillator, respectively.
- IF trimmers are in parallel with both primary and secondary windings of the IF transformers, #26 and &27 above.
Early Super-Heterodyne Sets

1927 Radiola 60: The first AC-powered Super Heterodyne.
Utilized a three-ganged, single-dial tuning condenser: one for the 1st RF amplifier, one for local oscillator, and one for the “mixer” or “converter” stage. Not all had trimmers!
Intermediate Frequency: 180 KHz
Another triple-ganged tuning condenser: each had a trimmer. Early tubes had fewer grids; utilized the plate to "mix" the signals. Intermediate Frequency: 260 KHz
Philco 70 Trimmers

Using an insulated tool:
1. Tune IF trimmers to 260 KHz
2. Tune high frequency trimmer to 1400 KHz
3. Tune low frequency trimmer to 700 KHz
Later Super Heterodyne Sets

1938 Zenith 6D-315 Wave-Magnet
“6-Tube” All-American Five

1939 Belmont 636

Utilizes a condenser-coupled broadband 1st RF amplifier rather than a tuned-circuit. C-8 passes any and all radio frequencies from the 12SK7 to the 12SA7. This type of coupling works, but is not as selective as coupling via a tuned-circuit.
Another “6-Tube” AA-5

Utilized a tuned, inductively-coupled RF amplifier stage for better selectivity. Other radios often utilized a broadband, inductively-coupled or condenser-coupled 1st RF amplifier.

From left to right, the trimmers and meshing plates on the triple-ganged tuning condenser vary the capacitance in the tuned circuits in the: 1) 1st RF amplifier to the Mixer tube; 2) the local oscillator; and 3) the antenna.
Aligning Other Bands

<table>
<thead>
<tr>
<th>SIGNAL GENERATOR</th>
<th>CONNECTION AT RADIO</th>
<th>DUMMY ANTENNA</th>
<th>BAND SWITCH SETTING</th>
<th>CONDENSER SETTING</th>
<th>ADJUST TRIMMERS TO MAXIMUM</th>
</tr>
</thead>
</table>
| **I. F.** 456 KC | Signal Grid of 1st Det. Connect at Slator of Large Gang Section. | .1 mf. | B Range | Turn Rotor to full open | 1st I. F. (C11) & (C12)
|                  |                     |               |                    |                   | 2nd I. F. (C13) & (C14) |

**RANGE B**

- **1730 KC**
  - Signal Grid of 1st Det.
  - .1 mf.
  - B Range
  - Turn Rotor to full open
  - Oscillator Range B (C4)

- **1500 KC**
  - Red Antenna Screw at Back of Loop
  - .1 mf.
  - B Range
  - Turn Rotor to max. output
  - Antenna Range B (C6)—See Illustration Page 1

- **600 KC**
  - Same as Above
  - .1 mf.
  - B Range
  - Turn Rotor to max. output
  - 600 KC (C8)
  - Rock Rotor—See Note A

**RANGE C**

- **6500 KC**
  - Same as Above
  - .1 mf.
  - C Range
  - Turn Rotor to full open
  - Oscillator Range C (C5)

- **6000 KC**
  - Same as Above
  - .1 mf.
  - C Range
  - Turn Rotor to max. output
  - Ant. Range C (C1)
  - Rock Rotor—See Note A

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5000 KC. The signal will then be heard at 5000 KC on the dial of the radio. The image signal, which is much weaker, will be heard at 5000 less 912 KC, or 4088 KC on the dial. It may be necessary to increase the input signal to hear the image.

1939 Airline 93WG-604
- AM and SW, with trimmers all over the place!
1937 Emerson AP-173
AM, 2 SW bands, with non-tunable wavetrap to by-pass
to ground any 456 KHz signal that could be on the
antenna. (Some sets add a trimmer condenser to make
it a tunable wavetrap. To tune, put 456KHz at the
antenna and adjust for minimum voltage)
Aligning FM

Note the Inductively-tuned RF stages (see enlargement at left)

Intermediate Frequency: 10.7 MHz

To align, use the same procedure as the AA5: 1) Align IF transformers to 10.7 MHz; 2) Align dial pointer to the dial scale; 3) Send a tone on an RF frequency into the set, tune the radio to that frequency, and adjust the antenna and oscillator trimmers to maximum AC voltage at the speaker voice coil.

1949 Zenith 7H-918 (FM-only)
In Conclusion

- **Alignment is the process of:**
  1. Precisely adjusting all the tuned circuits in a radio so that...
  2. Maximum power transfer from radio transmitter to receiving antenna to loudspeaker can occur.

- **Proper alignment will maximize your radio’s:**
  1. *Sensitivity* to distant or weak stations
  2. *Selectivity* to distinguish between close frequencies.

- **It’s Fun!**