STANDARD-FREQUENCY AND TIME-SIGNAL RADIO

The Stations That Broadcast Time Itself

WWV, WWVH and WWVB — and the world's other time stations, past and present

Presented by _______________________

Credit: NIST

AGENDA

What this covers

1. **What a time station actually does**
   The product is not a program. It is precision.
2. **How they modulate**
   AM you can listen to, keying you cannot, and some plain Morse
3. **The American trio**
   WWV, WWVH and WWVB
4. **WWV itself**
   The oldest voice on the air, and how close it came to ending
5. **Around the world**
   Who else is still transmitting time
6. **Silent now**
   The ones we have lost — including one this year

WHAT THEY DO

Their product is not a program. It is precision.

A time-and-frequency station is built around an atomic clock, and everything it sends is locked to that clock.

THE CARRIER

A standard frequency

Tune a receiver to WWV on 10 MHz and you have a 10 MHz reference good to a fraction of a part per billion — accurate enough to calibrate a lab oscillator.

ON TOP OF IT

The time

- A tick every second
- A tone at the minute
- A spoken announcement of the hour
- A digital time code a chip can decode

A chronometer check for mariners, a calibration reference for engineers, and the reason your kitchen clock sets itself twice a year.

THE ATOMIC CLOCK

The clock behind the tick

Since 1967 the second has not been a fraction of a day. It has been a count of oscillations in a caesium atom.

ONE SECOND =

9 192 631 770

cycles of the radiation from the hyperfine transition of an unperturbed caesium-133 atom.

Count to that number and a second has passed. Nothing about the Earth is involved.

1

Three caesium standards, on site

WWV and WWVH each hold three commercial caesium oscillators in three separate racks. One is designated the site master, and it drives the time code generator that feeds every transmitter.

2

Checked against Boulder every working day

The station standards are compared with UTC(NIST) in Boulder by GPS common-view measurement and steered when they need it. Station frequency is held to within a few parts in 10^{13}.

3

Transmitted almost perfectly. Received rather less so.

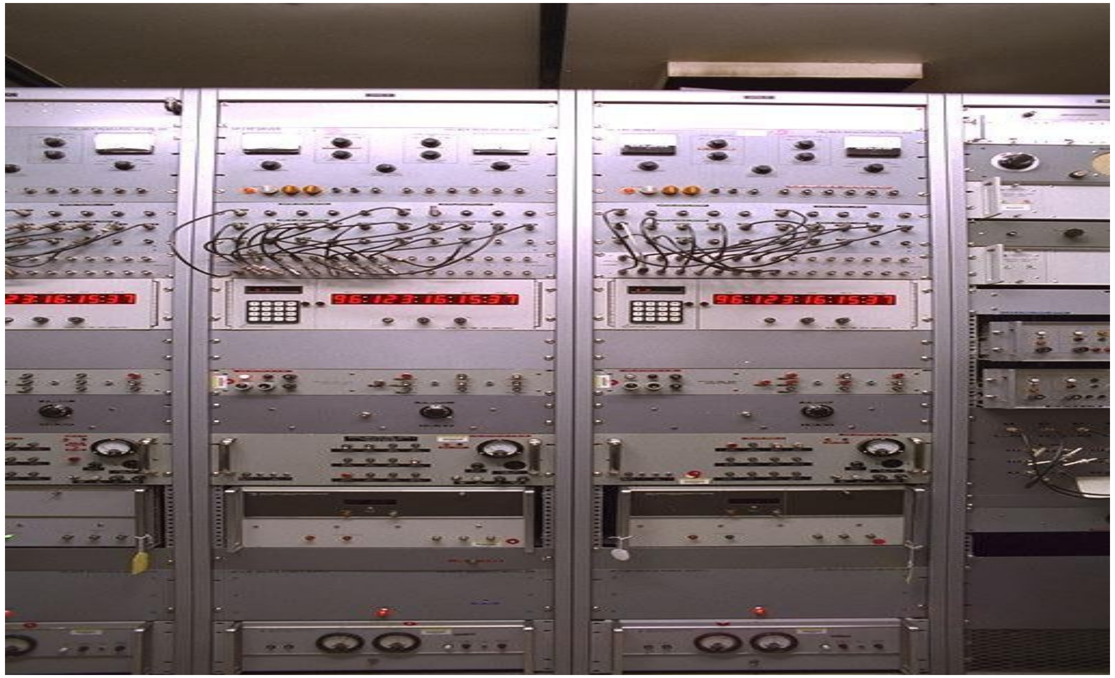
At the transmitter the time is within 0.0001 ms of UTC. By the time it reaches you it is good to under 10 ms — the loss is path delay, and it varies by up to a millisecond as the signal bounces off the ionosphere.

The error is in the path, not in the clock.

Everything that limits what you can do with WWV happens after the signal leaves the antenna.

THE CLOCK ROOMS

Three racks at each station



Fort Collins. The clock rack at WWV — the standards themselves, and the equipment that compares them.

Kauai. WWVH's time and frequency rack: digital recorders, a multi-channel chart recorder, and the station clocks.

One of the three is designated site master. It drives the time code generator, and that feeds every transmitter in the building.

Credit: NIST

WHAT THEY DO

Two families, two jobs

SHORTWAVE (HF)

Heard across oceans

WWV · WWVH · CHU · BPM · RWM

For generations this was how a ship checked its chronometer and a ham calibrated a rig.

LONGWAVE (LF)

Punch through walls

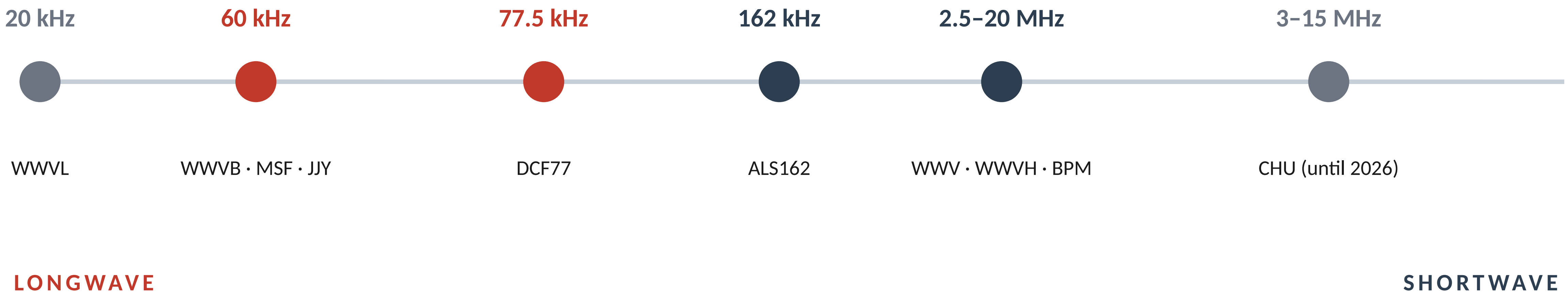
WWVB 60 kHz · DCF77 77.5 kHz · MSF · JJY

They do not travel as far — which is exactly what a self-setting alarm clock on a nightstand needs.

The earliest of all were a U.S. Navy experiment — the Naval Observatory was sending wireless time signals as a navigation aid by about 1904, two decades before broadcasting began.

WHAT THEY DO

Where they sit



Not to scale — the span from 20 kHz to 20 MHz is a factor of a thousand.

HOW THEY MODULATE

The shortwave stations are AM you can simply listen to

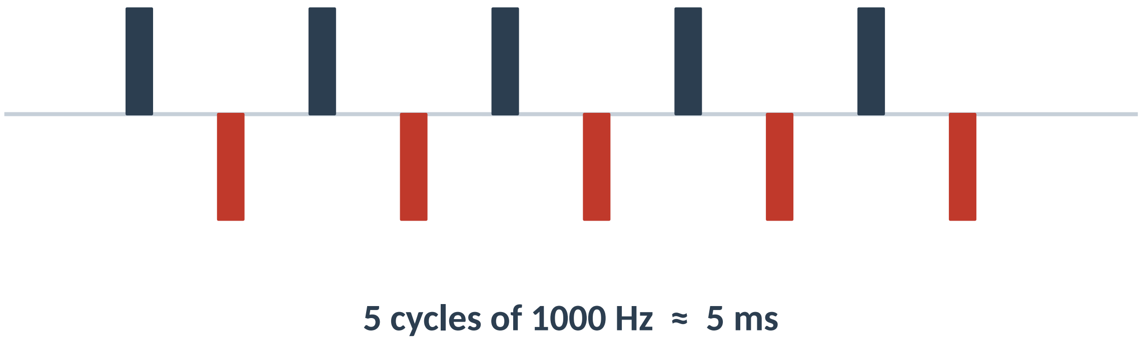
WWV and WWVH use ordinary double-sideband, full-carrier amplitude modulation — exactly like an AM broadcast station. Which is why you can tune 5 or 10 MHz in AM mode and just hear them.

The tick	Every second. On WWV, five cycles of a 1000 Hz tone — about 5 ms long.
Telling them apart	WWVH sends its tick at 1200 Hz, so the two can be distinguished on shared frequencies.
The minute	A longer 800 ms tone marks the top of each minute.
The hour	A 1500 Hz pulse.
Reference tones	Steady 500 Hz and 600 Hz alternate through the hour.
The voice	A man on WWV, a woman on WWVH, reading UTC.

HOW THEY MODULATE

Anatomy of one second

The on-time tick on WWV is literally five cycles of a 1000 Hz tone — about five thousandths of a second.



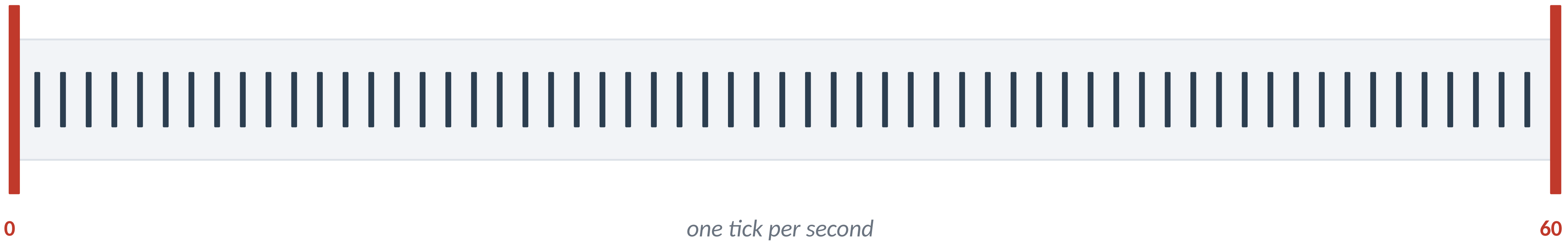
Why so short?

Because the tick has to be unmistakable and unambiguous. A short, sharp burst has a clean leading edge — and it is the leading edge that carries the time.

The ticks and markers run at full modulation while the tones and voice sit lower — so the on-time tick always punches through.

HOW THEY MODULATE

Anatomy of one minute



800 ms tone — marks the top of every minute

1500 Hz pulse — marks the hour

500 / 600 Hz — alternating reference tones through the hour

100 Hz subcarrier — the digital time code, one bit per second, underneath it all

HOW THEY MODULATE

The longwave clock-setters are keyed, not spoken

WWVB on 60 kHz carries no program at all.

It sends one bit per second, and nothing else.

That is amplitude modulation in the on-and-off sense — but fed to a speaker it would be clicks and hum, not something to listen to. Only a receiver chip decodes it.

Since 2012

WWVB has layered a second, phase-modulated code on top for tougher reception.

Germany's DCF77

Works the same way, and adds a phase-shift-keyed code that gives its signal a distinctive noisy hiss.

How WWVB sends a bit

At the start of each second the carrier power drops 17 dB. What the bit means depends entirely on when the power comes back.

One bit per second. Sixty seconds gives a clock chip the full time, date and daylight-saving state.

And a few are just Morse

Russia's RWM and its relatives send interrupted-carrier markers and Morse identification.

Straight on-off keying. No AM envelope at all.

In every case, the point to remember:

The rock-steady carrier frequency is the standard. The AM, the keying, or the Morse is only the wrapper that carries the time.

THE U.S. STATIONS

The American trio

All three are operated by NIST, with their clocks maintained by the Time and Frequency Division in Boulder, Colorado.

WWV Fort Collins, CO	**HF — 2.5, 5, 10, 15, 20 MHz**	On the air since 1920. Male voice. Ticks, tones, spoken UTC, time code, and hourly geophysical and GPS-status announcements.
WWVH Kekaha, Kauai, HI	**HF — 2.5, 5, 10, 15 MHz**	The Pacific sister station, since 1948. Female voice, so listeners hearing both can tell them apart.
WWVB Fort Collins, CO	**LF — 60 kHz**	No voice at all. Since 1963, now 70 kW ERP — the signal that sets tens of millions of clocks.

Twenty-three years on Maui, and then the move

Kihei, Maui, 1948 to 1971. The original WWVH, right at the water's edge — the reason the station eventually had to move.

Kokole Point, Kauai, today. The entrance sign inside the Pacific Missile Range Facility at Barking Sands.

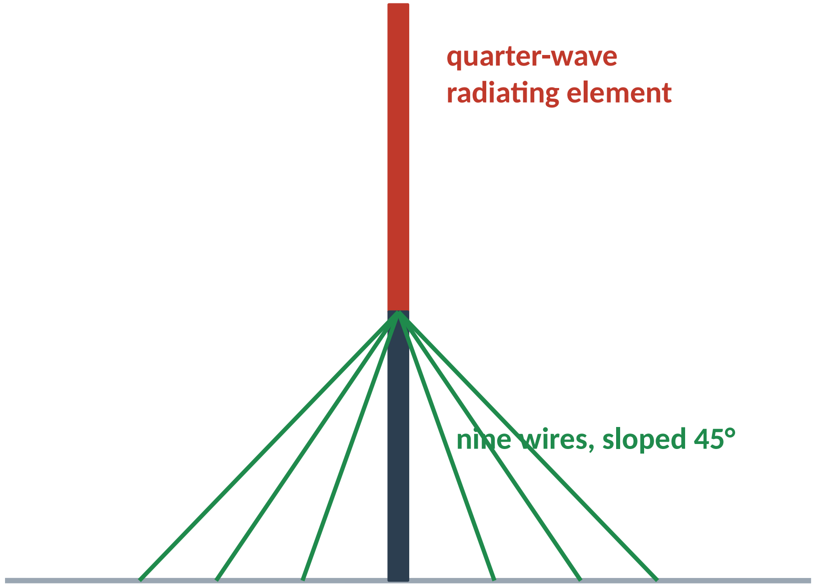
Salt air is the villain of this whole story — on Maui it ate the station, and on Kauai it is why the antennas are fibreglass.

Credit: NIST

THE ANTENNAS

WWV's antennas: half-wave verticals

Five antennas, one per frequency, each with its own transmitter. Every one is a half-wave vertical radiating an omnidirectional pattern.



they are the lower half of the antenna — and the guy wires

The elegant part

- Only the top half is tower. The bottom half is nine quarter-wave wires from the tower's centre, sloping to ground at 45 degrees.
- Those wires do two jobs at once — they radiate, and they hold the tower up.
- Heights follow the frequency: about 60 m at 2.5 MHz, down to roughly 7.5 m at 20 MHz.
- Each antenna has its own rigid coaxial feed — and the site is laid out so that no two lines ever cross.

Power: 10 kW on 5, 10 and 15 MHz · 2.5 kW on 2.5 and 20 MHz · the intermittent 25 MHz outlet runs 2.5 kW

How tall, and how much land

Antenna height is simply half a wavelength — so the whole field is one design built at six different sizes.

FREQ	WWV	WWVH
2.5 MHz	60 m · 197 ft	30 m · 98 ft ¼λ
5 MHz	30 m · 98 ft	30 m · 98 ft
10 MHz	15 m · 49 ft	15 m · 49 ft
15 MHz	10 m · 33 ft	10 m · 33 ft
20 MHz	7.5 m · 25 ft	—
25 MHz	6 m · 20 ft	—

Every WWV antenna is a half-wave vertical. At WWVH only 2.5 MHz is a quarter-wave. Nothing on either site is 5/8-wave.

WHAT ABOUT THE GROUND SYSTEM?

These are not quarter-wave monopoles standing on a radial field: the nine sloping wires are the lower half of the radiator, each about 0.354 of a wavelength. What lies under them is a separate question. A 10 kW site has a ground system — RF return, lightning, safety — and NIST does not publish what WWV's is.

THE LAND

- Fort Collins — 158 hectares, 390 acres, shared by WWV and WWVB.
- Kokole Point, Kauai — 30 acres.
- The gap is WWVB: its two antenna systems alone stand 2,810 ft apart.

Thirteen times the land at Fort Collins, and almost all of the difference is one 60 kHz antenna.

THE ANTENNAS

WWVH's antennas: and one of them aims

Four transmitters on a 30-acre site at Kokole Point, Kekaha — on the western edge of Kauai, inside the Pacific Missile Range Facility at Barking Sands.

MOSTLY OMNIDIRECTIONAL

Vertical monopoles and half-waves

- 2.5 MHz — a quarter-wave vertical, 5 kW.
- 10 and 15 MHz — omnidirectional half-waves, 10 kW each.
- Every frequency also keeps a standby antenna on a backup transmitter.

AND ONE PHASED ARRAY

Two elements, aimed west

Two half-wave vertical elements, separated horizontally by a quarter wavelength, phased to give a broad cardioid pattern with maximum gain directed west — out across the Pacific.

Rebuilt in fibreglass, not steel.

Between 2000 and 2007 the antennas were replaced with fibreglass-encased designs to survive the salt air — and built so they can be lowered to the ground for maintenance rather than climbed.

Two towers, and a beam aimed at the Pacific

The array itself: two half-wave vertical elements, a quarter wavelength apart. Phase them and the pattern leans west.

The field they stand in. Left to right: the abandoned 20 MHz array, then 15 MHz, then 10 MHz — with the Pacific behind.

This is the photograph that settles the argument — NIST captions it as the array, element spacing and all.

Credit: NIST

Who built the transmitters

Both stations run one transmitter per frequency, with standby units behind them. The hardware has been replaced far less often than you might expect.

WWV — FORT COLLINS

TMC, then CCA

- 1966 — Technical Materiel Corporation of Mamaroneck, New York, low bidder at $297,000: two GPT-40K sets at 10 kW, two GPT-10K sets at 2.5 kW, and two broadband standby sets able to run any WWV frequency.
- 1990 — new 10 kW transmitters for 5, 10 and 15 MHz from CCA Corporation. The TMC sets were reconfigured to 2.5 kW and kept as standby.
- The original GPT-10K pair ran continuously until 2008 — forty-two years.

WWVH — KAUAI

AEL, then Elcom-Bauer

- 1971 — seven transmitters built by AEL Corporation went in when the station moved from Maui to Kauai.
- 1983 — two of them were pulled and three more efficient Elcom-Bauer units took their place.
- Today: three Elcom-Bauer at 10 kW on 5, 10 and 15 MHz; one AEL at 5 kW on 2.5 MHz; and four AEL standby sets at 5 kW each.

Fifty-five years of service from four manufacturers, and a good deal of the original iron is still in the building.

THE TRANSMITTERS

At what power?

Radiated power, frequency by frequency. Each figure is one transmitter feeding one antenna.

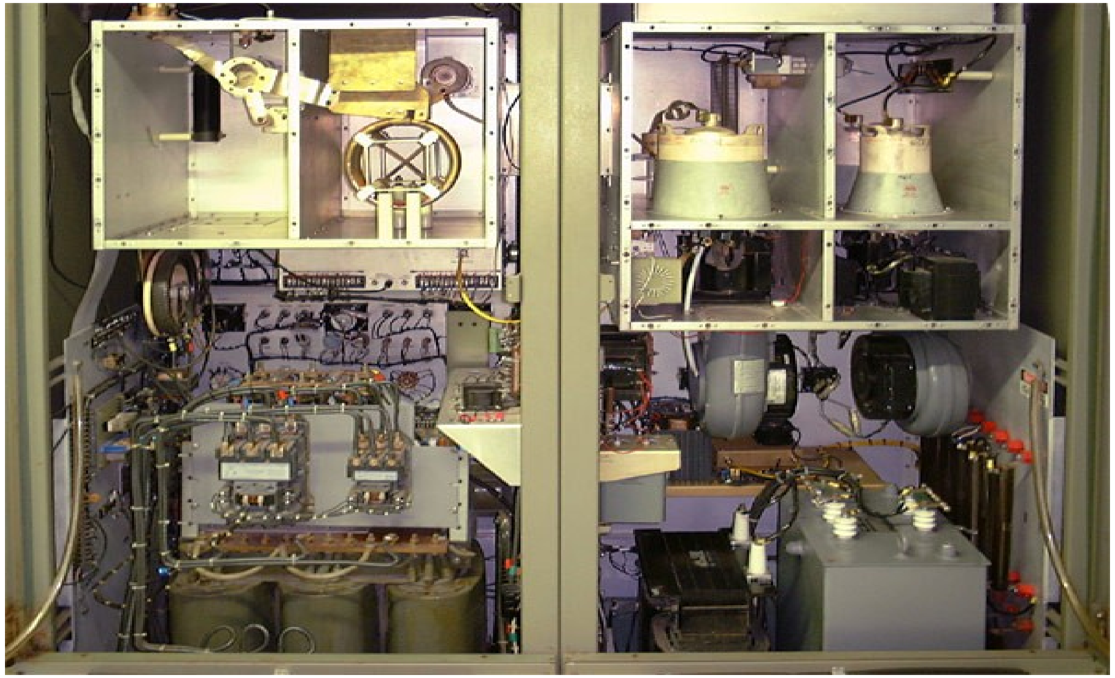
FREQUENCY	WWV · FORT COLLINS	WWVH · KAUAI
2.5 MHz	2 500 W	5 000 W
5 MHz	10 000 W	10 000 W
10 MHz	10 000 W	10 000 W
15 MHz	10 000 W	10 000 W
20 MHz	2 500 W	*not broadcast*
25 MHz (experimental)	2 500 W	*not broadcast*

Put that beside your own station.

Ten kilowatts is roughly seven times the U.S. amateur legal limit — and it is run into a single half-wave vertical, twenty-four hours a day, with no programme to interrupt it.

Ten kilowatts, with the doors open

Fort Collins. The 5 MHz transmitter — one of the 10 kW units, front panel, meters and all.



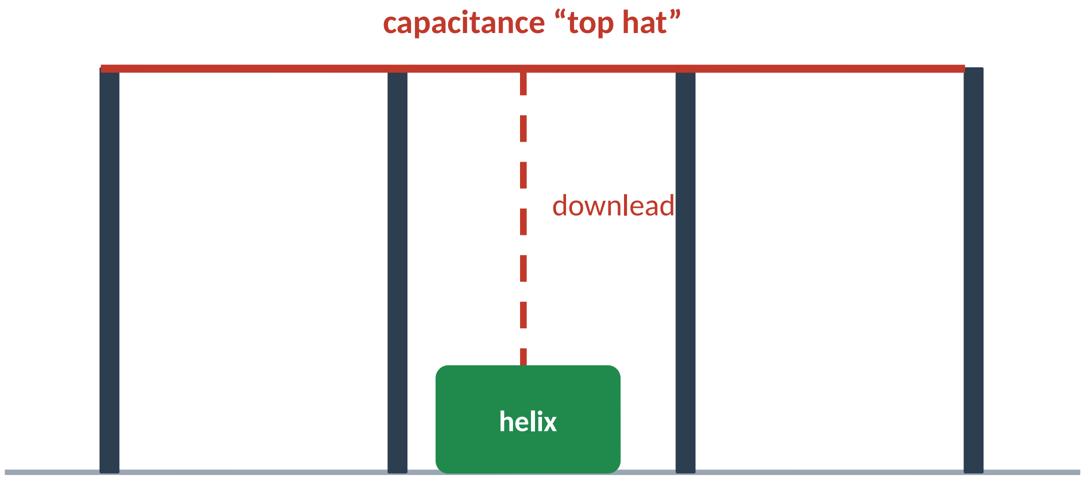
Kauai. Inside a 10,000-watt Class C plate-modulated transmitter. Tubes, tank circuits and transformers you can point at.

Nothing here is miniaturised. This is broadcast iron, run continuously, and much of it is older than most of the audience.

Credit: NIST

And then there is the 60 kHz problem

A quarter wavelength at 60 kHz is about 1,250 metres. Nobody builds that. WWVB's towers are 122 metres — roughly a tenth of what the physics wants.



four 122 m towers in a diamond

How they make it work

- A cable “top hat” slung between the four towers adds capacitance the short antenna lacks.
- A helix house underneath holds a huge inductor to cancel that capacitance, plus a variometer to tune it.
- Two identical antennas, 857 m apart, both built in 1962 and refurbished in 1999.
- The north one was built for WWVL on 20 kHz — when that closed in 1972 the antenna was kept.

51 kW of forward power from each transmitter — to put 70 kW of effective radiated power in the air.

Four hundred feet, to fake four thousand

The towers across the field. Four 400-foot towers hold up one antenna system, and there are two of them, 2,810 feet apart.

Busing on top of the helix house — the insulator and hardware where the power leaves for the down lead.

A true quarter wave at 60 kHz would stand 4,100 feet tall. Nobody builds that. The top-hat and the helix house stand in for the missing height.

Credit: NIST

INSIDE THE HELIX HOUSE

The coil that makes an impossible antenna resonate

The helix house near completion. The white down lead is not yet connected to the antenna matching equipment.

The old antenna tuning variometer, now retired. Moving it changes inductance to hold the antenna in tune.

The antenna is electrically far too short, so it looks capacitive. The helix house supplies the inductance that cancels it out.

Credit: NIST

WWV: the oldest voice on the air

On the air since 1920 — the world's longest continuously operating radio station.

Older than the entertainment broadcasters whose band it sits above.

1923	Already sending standard-frequency signals to the public, so the booming new radio industry could calibrate its gear.
1945	Carrying official U.S. time, maintained jointly by NIST and the U.S. Naval Observatory.
(303) 499-7111	And you can still simply phone the time.

Where WWV has lived

1920

Washington, D.C.

on the air

1931

suburban Maryland

a series of sites

1966

Fort Collins, Colorado

its present home

A century in three places — and it very nearly ended in the fourth.

In 2018 the plan was to switch it off altogether. That story is the next slide.

2018

The year it almost ended

In August 2018 the amateur community learned that NIST's Fiscal Year 2019 budget request proposed shutting down WWV and WWVH.

$6.3M	$629M	~1%
the saving proposed	the total NIST request	of the agency's budget

A century of continuous transmission, and the world's oldest radio station, came down to roughly one percent of one agency's budget.

And then people wrote in.

Hams, mariners, timekeepers and clock-watchers objected loudly. The ARRL raised the alarm, the shortwave community campaigned, Congress preserved the money — and by March 2019 the funding was restored. WWV reached its centenary the following year.

The frequency that came back

1977	NIST drops both the 20 and 25 MHz outlets
1978	20 MHz returns the following year
37 years	25 MHz stays dark
2014	A listener's emailed request prompts WWV's lead engineer to switch it back on

“For old times' sake,” on an experimental basis — and it has lived on intermittently ever since, useful mainly as a propagation beacon for 10 and 12 metres.

Two favourite footnotes

1958

Tracking a dying Sputnik

WWV's 20 MHz signal was used to track Sputnik 1 by meteor-scatter, after the satellite's own electronics had failed.

2021

A deliberate burst of noise

Once an hour, WWV and WWVH carry an odd burst of tones, chirps and noise — a joint experiment with the ham-radio HamSCI project to study the ionosphere.

If you have ever heard something strange on WWV and assumed your receiver was faulty — it probably was not.

STILL TRANSMITTING

Around the world today

DCF77	Mainflingen, Germany	**LF — 77.5 kHz**	PTB, since 1959. Sets most of Central Europe's clocks; now also carries civil-protection alerts and weather data.
MSF	Anthorn, England	**LF — 60 kHz**	“Time from NPL.” Moved here in 2007 from its historic home at Rugby.
JJY	Fukushima & Kyushu, Japan	**LF — 40 & 60 kHz**	Two NICT stations covering all of Japan, on the same 40/60 kHz pair used by clock chips elsewhere.
BPM	Pucheng, China	**HF — 2.5, 5, 10, 15 MHz**	China's National Time Service Center, with longwave sister BPC on 68.5 kHz.
RWM	Moscow, Russia	**HF — 4996, 9996, 14996 kHz**	Continuous Morse-and-markers standard frequency. Russia also runs longwave RBU.
ALS162	Allouis, France	**LF — 162 kHz**	Rides the old France Inter longwave transmitter — the programming ended in 2016, the time signal did not.

Also on the air at various times: YVTO (Venezuela), HLA (South Korea), ATA (India), LOL (Argentina), BSF (Taiwan).

A CLOSER LOOK

JJY: Japan's century of timekeeping

On the air 30 January 1940 — the world's second national standard-frequency station, behind only WWV. For most of its life it was a shortwave broadcaster as familiar across the Pacific as WWV itself.

1940

Shortwave begins

4, 7, 9 and 13 MHz

Late 1950s

The international set

2.5, 5, 8, 10 and 15 MHz

1999–2001

Down to longwave

40 kHz, then 60 kHz

That 8 MHz channel was a JJY signature — most of the world's time stations skipped it. The shortwave service signed off for good on 31 March 2001.

A Japanese woman's voice announced the time before every tenth minute: "JJY JJY 1630 JST."

WHAT WE HAVE LOST

Silent now

CHU	Ottawa, Canada	HF — 3330, 7850, 14670 kHz	2026
Loran-C	U.S. & worldwide	LF — 100 kHz	2010
HBG	Prangins, Switzerland	LF — 75 kHz	2011
JJY (HF)	Japan	HF — 2.5 to 15 MHz	2001
VNG	Llandilo, Australia	HF	2002
Omega	worldwide, 8 stations	VLF — ~10–14 kHz	1997
OMA	Liblice, Czechoslovakia	LF — 50 kHz	1995
WWVL	Fort Collins, CO	VLF — 20 kHz	1972

Several were retired as satellite navigation made a steady terrestrial reference seem less essential — though jamming and indoor reception keep the old stations relevant.

The newest loss

CHU — Ottawa. Switched off 22 June 2026.

Canada's official time signal for more than a century, and the shortwave neighbour North Americans knew best after WWV.

Bilingual	English and French voice announcements
Unusual signal	Reduced-carrier single sideband, not the plain AM of WWV
Why it went	A budget measure by the National Research Council
What is left	Telephone, a web clock, and network time protocol

THE LAST VOICES

Who is still speaking?

With CHU gone, a natural question: is anyone else out there still announcing the time in a human voice?

WWV	Fort Collins	English, male	**ON THE AIR**
WWVH	Kauai	English, female	**ON THE AIR**
YVTO	Caracas	Spanish	**REPORTED ON AIR**
CHU	Ottawa	English & French	**SILENT 2026**
JJY (HF)	Japan	Japanese, female	**SILENT 2001**

BPM, RWM and every longwave station send tones, Morse or code — no voice at all.

WHAT THEY ARE FOR US

Why amateur radio has always leaned on them

Every one of these uses comes from the same property: a time station is the one signal on the band whose frequency, timing and behaviour you can trust absolutely. That makes it a measuring stick for everything else.

1. **Calibrating the rig**

   Zero-beat against a carrier that is right to a fraction of a part per billion. Before cheap frequency counters, this was how you knew where your VFO actually was.

2. **Reading the band**

   If 15 MHz is booming and 20 is silent, the band has told you something. WWV's intermittent 25 MHz outlet survives mainly as a propagation beacon for 10 and 12 metres.

3. **Space weather, hourly**

   WWV carries geophysical and GPS-status announcements every hour — propagation information delivered by the same signal you are using to judge propagation.

4. **Knowing the time that matters**

   UTC, spoken aloud, for logs, schedules, nets and contests — with no clock of your own to trust or set.

5. **Doing science with it**

   Since 2021 WWV and WWVH carry an hourly burst of tones and noise for the HamSCI ionospheric experiment. In 1958 the 20 MHz signal tracked a dying Sputnik by meteor-scatter.

WHAT REPLACED THEM

So what is the standard now?

UTC is the world's time standard — and always was.

Coordinated Universal Time, kept by international agreement from atomic clocks in national laboratories. The time stations never were the standard — they were one way of delivering it.

What changed is the delivery:

GPS

Global Positioning System

A satellite constellation carrying atomic clocks. Your receiver works out where it is from how long each signal took to arrive — so it is a timing system first and a navigation system second.

NTP

Network Time Protocol

How almost every computer and phone on earth sets its clock, over the internet, without anyone thinking about it.

The old way

A carrier in the air

A signal you can receive with a wire and a diode, from a transmitter you can point at on a map.

GPS did not replace the time stations with a better time signal. It replaced them by putting an atomic clock in everyone's pocket for the price of a chip.

WHY THEY STILL MATTER

A signal in the air needs no account, no subscription and no network.

It simply arrives.

GPS can be jammed. The internet can be down. A satellite constellation is operated by somebody, somewhere, who can switch it off. A carrier on 60 kHz just arrives — and every station that closes is one fewer way to know what time it is without asking permission.

Questions?

Credit: NIST

TAKE THIS AWAY

Where to read the detail

Everything in this talk is written up at greater length, free, with no sign-up and nothing for sale.

Time Stations	The full version of this talk, with every station listed
Shortwave from America	U.S. international broadcasters, past and present
AM Broadcast Band Trivia	The other end of the dial
NIST Time and Frequency Division	The official source for WWV, WWVH and WWVB

n6jet.com