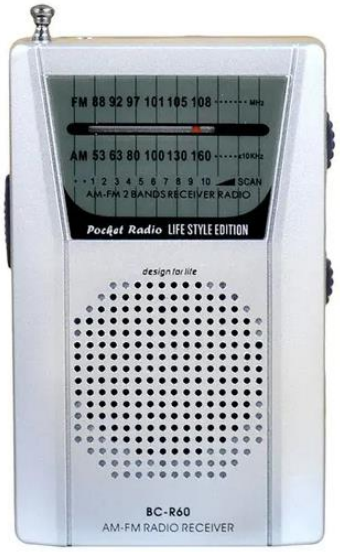
REVERSE ENGINEERING CHALLENGE

VIQC ELEMENTARY SCHOOL

Disassembly and exploration of Radio



BC-R60 Homeware AM/FM RADIO

Frequency range

FM: 88-108 MHz

AM: 530-1605 kHz

TEAM 8390V

Derek Ban & Zirui Qin

Caution Tape Robotics

Markham, ON, Canada

Table of Contents

1.0 Summary Report

We absorbed in this online challenge because Reverse Engineering, Geography, and Chemistry have always been my brother's and my favorites. We are the best partner of the 8390V team, participating in the Vex IQ tournament 2023, and we couldn't find better words to describe our excitement!

We chose to disassemble a radio since we're studying the radio and radio waves. It all started with a CNN news about FRBs (fast radio burst in space has a 'heartbeat' pattern) in July, which greatly aroused our curiosity. You might think "radio" is a gadget you listen to, but it also means something else. It can be as simple as being made by any person in their home for a few bucks, or as complex as detecting and contacting other life in the universe. That's why we are fascinated by it! Over the last Century, radio has radically changed the course of Humanity and rapidly accelerated the growth of the Information Age.

At first, we wanted to do this challenge because of our interest, but we learned much more than we expected when we finished it. From researching to disassembling and analyzing every single part to organizing all the results on the paper, we learned from uncountable websites, videos, and even books. We encountered many difficulties at each step and almost gave up a few times, but today I am proud to say we made it. Learning robotics is learning how to solve problems (better). However, it doesn't matter how far you might rise; at some point you are bound to stumble because if you're constantly doing what you do and pushing yourself higher, you will at some point fall. This is particularly similar to our Vex Robot, where every time we cheer for a higher score or get out of a jam, the next problem follows. But here's the key, learn from every mistake because every experience, encounter, and particularly your mistakes are there to teach you and force you into being more who you are. And then figure out what is the next right move.

Of course, you must have three essential factors. (1) Teamwork. The 21st Century is different from the era in which Einstein and Tesla lived, and we can hardly create the miracle by ourselves. (2) Optimism, which can make you go farther. (3) Time, the thing you cannot understand today, you may understand tomorrow. "I'm convinced that the only thing that kept me going was I loved what I did." Steve Jobs said, and we agree with it.

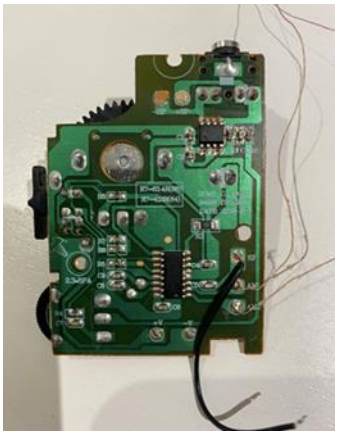
The main reason we could go to the end was the strength of the teamwork. Meanwhile, thank you to all the coaches and teammates of the club; the time we spent with you every weekend working on Vex IQ was the most enjoyable.

That is us, 8390V! With a passion for life and dreams, we were, are, and will. (486 words)

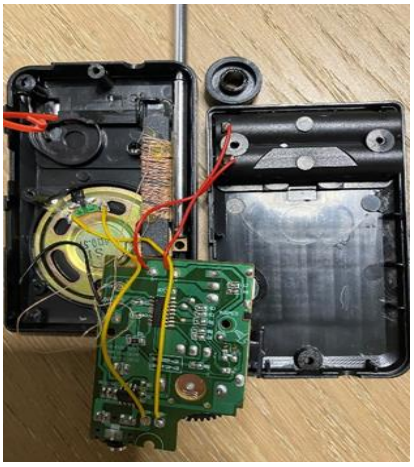
2.0 Disassembly Procedure

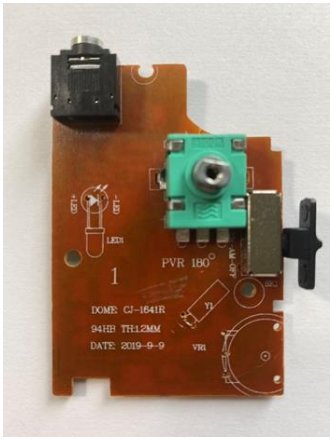
Step 1: We carefully opened the battery panel at the bottom of the back side and found screws that gave us access to the interior. Then, we opened the three screws that we have here.

Note: I got six screws from this radio (since you may have more than sixty screws from other devices), and those screws have different types or lengths usually, so we should mark that those are the screws from a different part.



The front of the main board



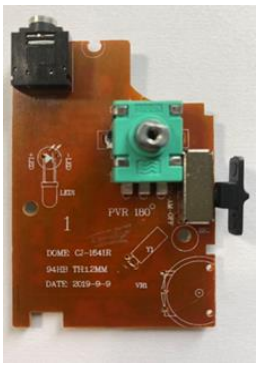


The back of the main board

Step 2: When I opened it, it took me a while to figure out how that works because it is a current radio with PCB produced in 2019, slightly different from the vintage radios. We also disassembled an intelligent player and an old radio to compare their internals. I will show more details later.

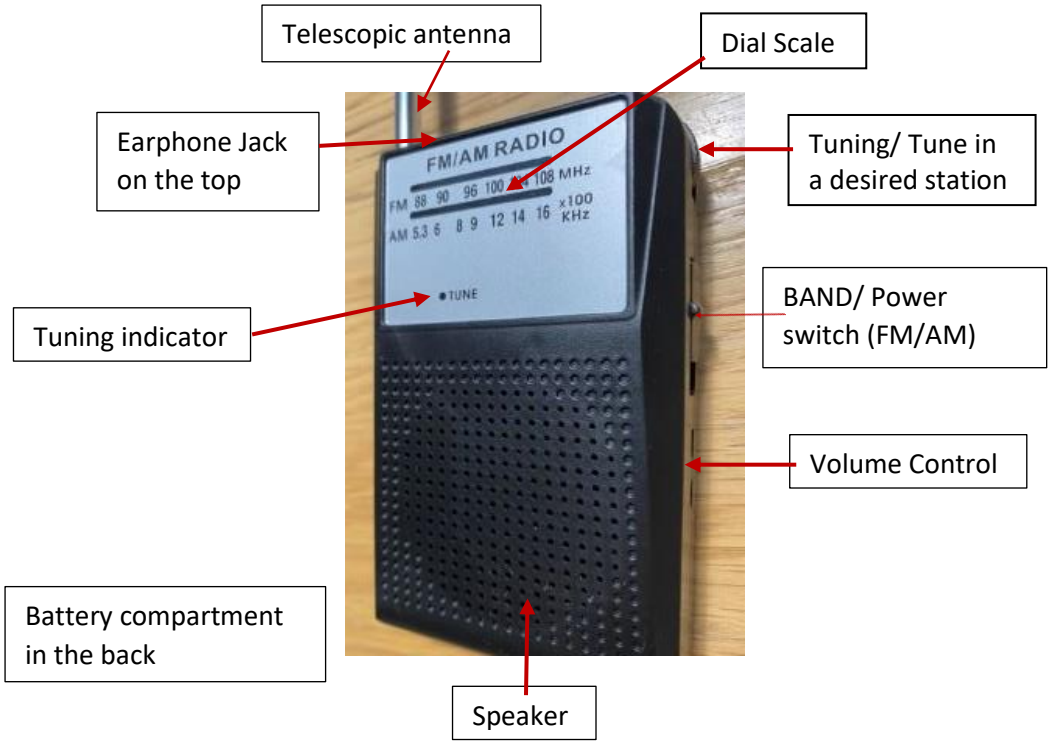
Step 3: Firstly, we must remove the wires connected to the battery compartment and the speaker. Most of the parts were attached to the inside of the plastic case in front of the radio—for example, FM Antenna, AM Antenna Coil, volume control, and speaker.





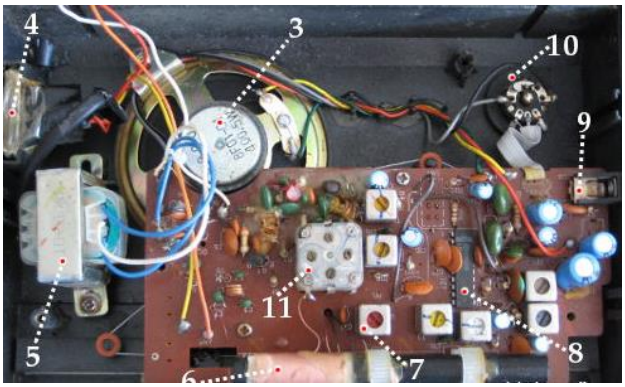
Step 4: Finally, we disassembled all the parts we knew in order: wires, FM antenna, AM antenna coil, speaker, tuning knob, LED, and BAND/Power switch. But not includes chips, an earphone jack, and a variable capacitor because those parts are soldered to the PCB and look very fragile. We could break something easily.

3.0 External Analysis



4.0 Inside components and the function

4.1 Vintage Radio



Picture is the internal structure of my grandfather's vintage radio. Probably produced in 1975-1980.

Parts 1 (External FM antenna) and 2 (Battery compartment) are not included in the picture, as they are external parts.

1. External FM antenna: The one on this radio extends to about 30 cm (1 ft), which is plenty long enough to catch a good range of FM broadcasts. You can extend and swivel the telescopic antenna for better reception. Generally speaking, the longer the antenna, the more signals you can pick up.

2. Battery compartment: This radio is either battery or AC powered. When you plug in an AC lead, a switch automatically cuts out the battery power.

3. Loudspeaker: There is only one loudspeaker, so this radio can reproduce only mono sounds. Generally, the bigger the loudspeaker the louder the radio (and the better the quality of sound it will make).

4. AC power input: A cable plugs into this socket so you can run the radio economically from a domestic power supply.

5. Transformer: The radio's electronic components operate on very small voltages (less than 6 volts), but the power that comes in from the AC outlet is typically 110 volts (in Canada), 220 volts (in China). The transformer's job is to scale down the AC voltage so it's safe and appropriate for the radio's delicate components.

6. Internal AM antenna: When you're listening to an AM (also known as MW or medium wave) broadcast, the external FM antenna is redundant. Instead, signals are picked up by this tightly coiled AM antenna

concealed inside the case. If you're listening on AM, you have to turn the entire radio to reorient the built-in antenna and improve your signal reception.

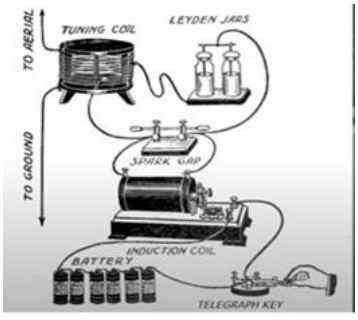
7. Transformer: A series of smaller transformers help the radio hone in on just the station you want by blocking out other, nearby stations.

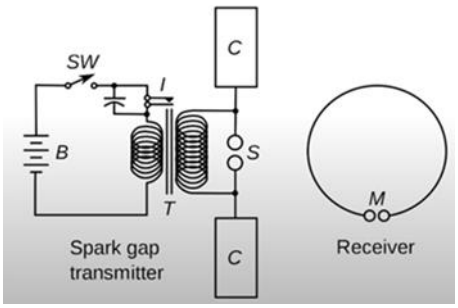
8. Amplifier: This small chip boosts the signal strength so it's powerful enough to drive the loudspeaker. The amplifier is based on transistors, electronic components that take in a small current and put out a much larger one—scaling it up in size. Small radios are often called "transistor radios". Before transistors came along, radios were typically huge wooden boxes that stood in the corner of your home, as big as an old-fashioned TV (and often even bigger).

9. Earphone socket: You can plug a small mono earphone in here to listen in privacy. If you plug stereo headphones into the mono socket, you'll hear sound in only one of the two earpieces.

10. Volume control: This is the back of the volume knob. Turning the volume knob adjusts an electronic component called a variable resistor or potentiometer, which increases or decreases the electric current flowing to the loudspeaker. A bigger current makes a louder sound with more volume; a smaller current makes a quieter sound with less volume.

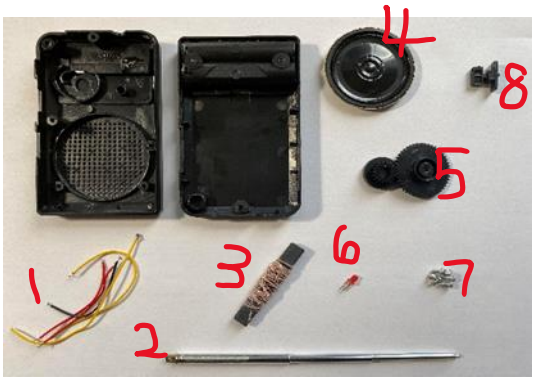
11. Variable capacitor tuner: The tuner usually employs the combination of an inductor (for example, a coil) and a capacitor to form a circuit that resonates at a particular frequency. This frequency, called the resonant frequency, is determined by the values chosen for the coil and the capacitor. This type of circuit tends to block any AC signals at a frequency above or below the resonant frequency. You can adjust the resonant frequency by varying the amount of inductance in the coil or the capacitance of the capacitor. In simple radio receiver circuits, the tuning is adjusted by varying the number of turns of wire in the coil. More sophisticated tuners use a variable capacitor (also called a tuning capacitor) to vary the frequency.

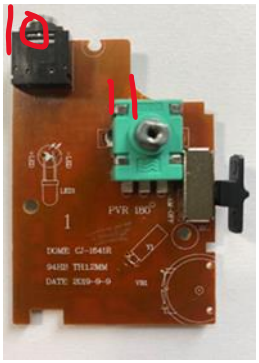




4.2 Current Radio

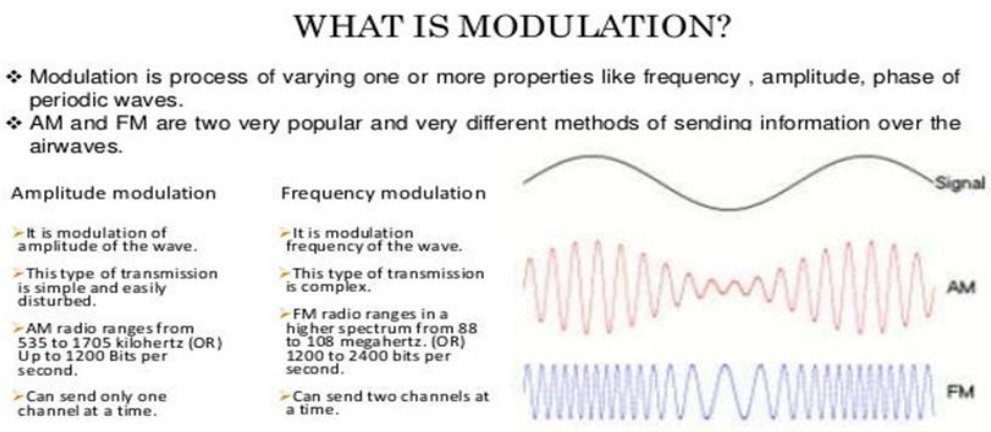
This is the AM/FM Radio we bought in Walmart and it produced in 2019-2021. Current radio is much simpler inside than vintage radio. Many complex parts have been replaced by integrated circuit. The functionality is almost the same, but I believe the latter has a more efficient manufacturing process.





1) Wires; 2) External FM antenna; 3) Internal AM antenna; 4) Loudspeaker; 5) Tuning knob; 6) Led; 7) Screws; 8) Power switch (FM/AM/OFF); 9) RF amplifier, mixer, IF amplifier, detector, and AF amplifier on Integrated circuit; 10) Earphone socket; 11) Variable capacitor tuner.

4.3 How does a radio work?



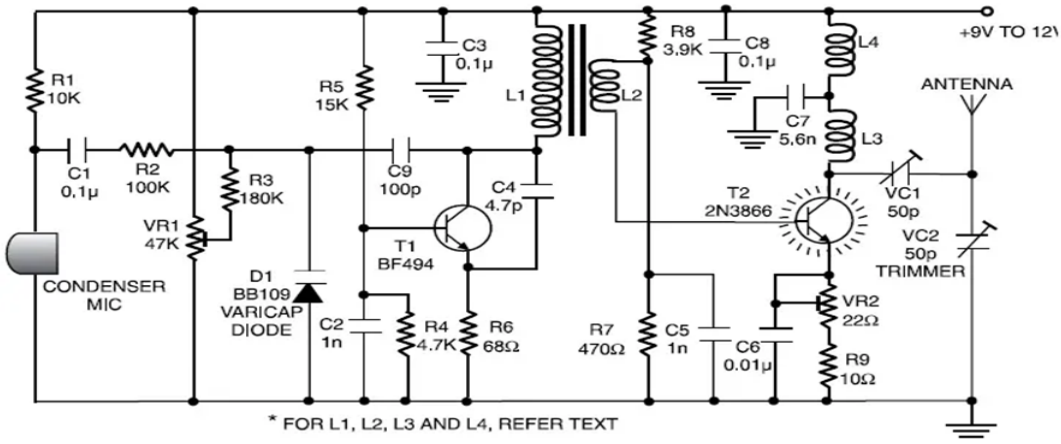
Today's radios use sine waves to transmit all sorts of information from audio to video to raw data by utilizing sine waves for transmission. Radios in devices can distinguish different channels based on frequency, or the number of cycles in the sine wave, or second. This allows 10s to 100s to 1000s of channels on modern radios all in the same space without too much interference.

The problem is that sine waves don't natively carry any information. They provide a foundation for transmitting information, like the crackers are the foundations to the marshmallow sandwiches, or like the box for birthday cake, we actually need is the cake, not the box, but we do need a box to deliver it. In order to get sine waves to actually carry information you need to modulate it. You can do this in three ways, pulse modulation, amplitude modulation and frequency modulation.

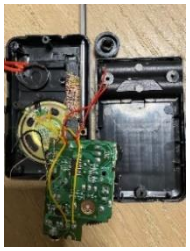
(1) Pulse modulation means that you turn the sine wave on and off just like the IT guy suggested. Doing this allows you to easily send Morse code but that's just about it.

(2) Amplitude modulation is what is utilized by AM radio stations and TV signals to encode data in this format. You can imagine this as the wave from a person's voice being combined with a sine wave to create a new rather complex sine wave with the same frequency but with a lot more data inside.

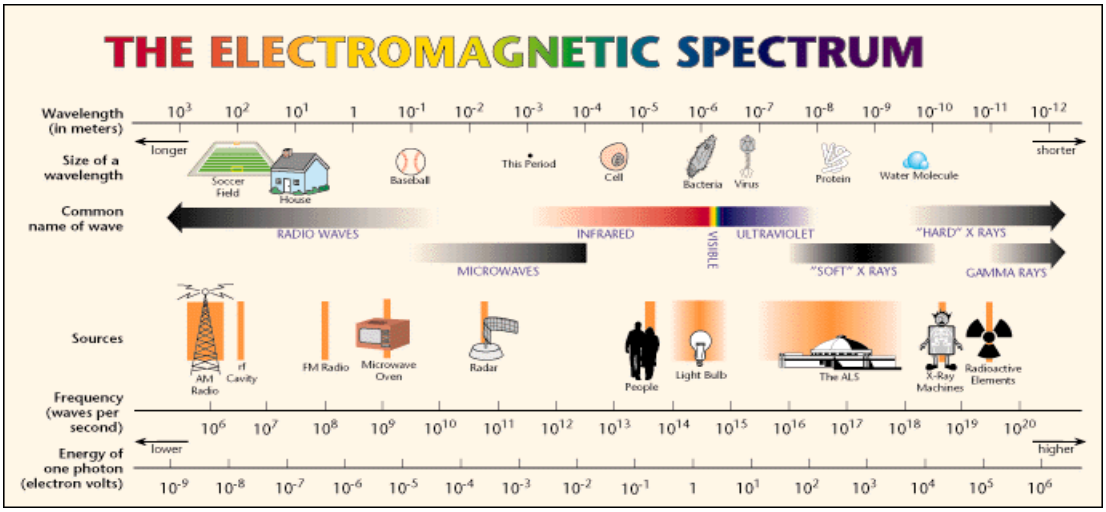
(3) Finally, frequency modulation (FM) is used for FM radio and in tons of other wireless techs. In this encoding technique, the sine wave frequency changes slightly based on the signal. This means that the distance between the peaks of the waves is varied based on the data that's trying to be transmitted. FM radios have different detector setups and translate frequency in the sound rather than amplitude. But otherwise, they operate in the same way data can be encoded onto a constantly changing signal utilizing different modulation techniques. that have advantages and disadvantages to each method. Nearly everything that communicates wirelessly around us uses radio waves to do so.



5.0 Comparison of similar products

	Vintage radio **VS.** Current radio **VS.** Smart Speaker		
Main Board	 PCB with complex parts and wires	 PCB with few wires and chips	 PCB with Integrated Circuit Just two flat end Cable
Speaker	 Thickness: 3-5 mm Tone quality: ★	 Thickness: 3-5 mm Tone quality: ★★	 We can see this bass port is folded and it looks pretty long. I think that might be one of the secrets behind the real deep bass that the speaker delivers. Tone quality:★★★★
Appearance			
Disassembly and assembly difficulty Level 1-5	 Level 3	 Level 1	 Level 1
*Notes:	Modern digital radio breaks the signal into pieces coded as numbers which are reassembled into sound at the receiver. They are transmitted across much wider frequency bands than analog radio. This gives a more reliable signal, and it means one digital signal can carry many programs at the same time.		

6.0 What are radio waves?



Radio waves are part of the electromagnetic spectrum. And they have the longest wavelength and the lowest frequency of all of the electromagnetic waves. The reason that we call this whole spectrum electromagnetic is that they're made up of oscillating electric and magnetic fields.

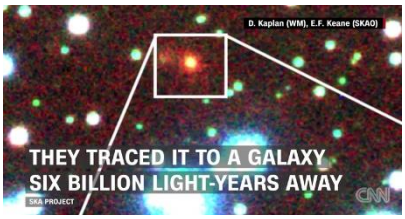
You don't really need to understand what this means if you're not interested in science. You just need to know that we can generate them using electricity in the form of an alternating current. Because alternating currents are made up of oscillating charges. And the cool thing is that we can use this basic method to transfer information or pretty much any kind, not just basic numbers. In fact, the main use of radio waves is for communication. And there are three types that you need to know about the long wave, short wave and very short-term wave.

long wave radio waves can be transmitted huge distances, like from London to Singapore without having to interact with anything along the way. This is because they diffract or bend around the curved surface of the earth. So, they're great for long range communication.

Shortwave radio signals can also travel long distances, but they're not able to curve around the Earth. Instead, they reflected from the ionosphere which is an electrically charged layer of the Earth's upper atmosphere. So, by bouncing back and forth repeatedly, they can cover long distances. shortwave radio can also be used to send data over short distances though, like for Bluetooth and your phone

The last type are very short radio waves were to use for TV and FM radio. And these ones have to travel directly from the transmitter to your receiver. which is why you don't always get a great radio signal when you're in the car Because surrounding structures like hills and tunnels can get in the way of that direct transmission.

7.0 Radio in Universe - FRB



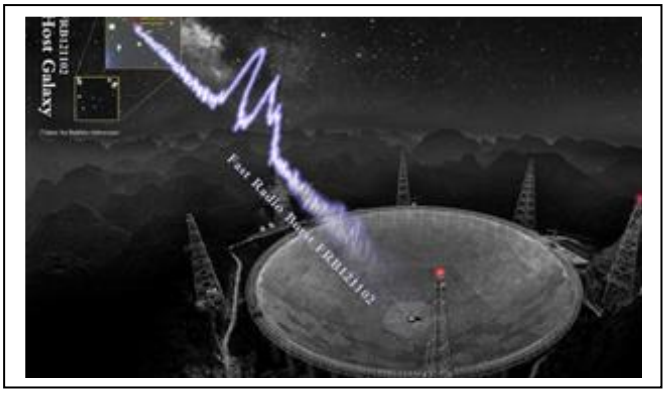
A mysterious fast radio burst in space has a 'heartbeat' pattern

A mysterious radio burst with a pattern similar to a heartbeat has been detected in space. Astronomers estimate that the signal came from a galaxy roughly a billion light-years away, but the exact location and cause of the burst is unknown.

Fast radio bursts, or FRBs, are intense, millisecond-long bursts of radio waves with unknown origins. The first FRB was discovered in 2007, and since then, hundreds of these quick, cosmic flashes have been detected coming from various, distant points across the universe. Many FRBs release super bright radio waves lasting only a few milliseconds at most before disappearing completely.

The signal, named FRB 20191221A, lasted for up to three seconds – which is about 1,000 times longer than typical fast radio bursts. "It was unusual, not only was it very long, lasting about three seconds, but there were periodic peaks that were remarkably precise, emitting every fraction of a second — boom, boom, boom — like a heartbeat...

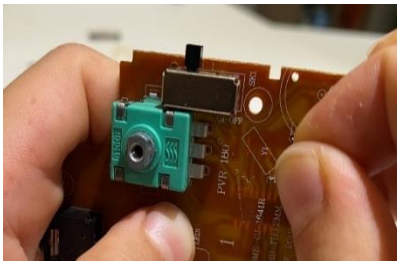
-By Ashley Strickland, CNN, Wed July 13, 2022

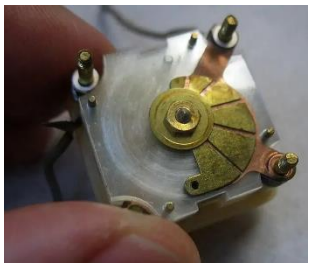


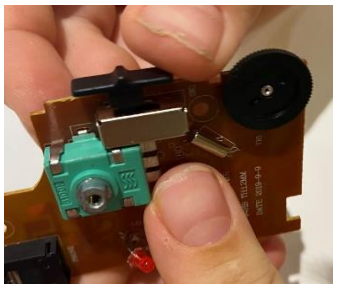
Today, many scientists get together to discuss the possibility of interstellar transmission technology. If we can receive the radio from the universe, maybe humans could develop such long-distance communication tech. The president of METI is Douglas Vakoch, he's a renowned astrobiologist. This science is concerned with the evolution of the universe. For a long time, he's been working on interstellar messaging, but he's also well aware that human senses might not exactly work with alien senses, even if we could send messages to other galaxies.

However, we think the radio is the method we might try. That's why we want to study Robotics, AI and Radio, because it's a set of keys that could unlock the mysteries of the universe.

8.0 Team photo album






I want to end this report with pictures of our "damaged" fingers and fingernails to mark our growth in Vex IQ.

Aside from the knowledge we obtained about electronics, we also learned about the significance of good research and how to use tools. When we disassembled the smart speaker, there were four screws in the corner, and we didn't have a Special screwdriver. So we improvised by folding the screwdriver to almost 90 degrees and successfully solved the problem.

If you want to play the Vex IQ to a higher level, dream of being a scientist in the future, or even want to succeed in any field, you must go through the same process in general. (1) What do you want to do? (2) find what the problem is? (3) Do research and take a note about what you are trying to find out, and you can also look at other people's ideas. That is why the Engineer notebook is essential. (4) Test it to see if it will work on a device or anything. (5) If no, do steps 1-5 again. (6) If yes, think about if you could make it better.

Annex I

A brief history of radio

This foundational communication tech can be dates to 1894. Over the last century, radio has radically changed the course of Humanity and rapidly accelerated the growth of the Information Age.

Photo: Italian Radio pioneer Guglielmo Marconi.
Photo courtesy of US Library of Congress

- 1888: German physicist **Heinrich Hertz** (1857–1894) made the first electromagnetic radio waves in his lab.
- 1894: British physicist **Sir Oliver Lodge** (1851–1940) sent the first message using radio waves in Oxford, England.
- 1897: Physicist **Nikola Tesla** (1856–1943) filed patents explaining how electrical energy could be transmitted without wires and later (following Marconi's work) realized they could be adapted for wireless communication (Radio) as well. The following year, Tesla was granted US Patent 613,809 for a radio-controlled boat.
- 1899: Italian inventor **Guglielmo Marconi** (1874–1937) sent radio waves across the English Channel. By 1901, Marconi had sent radio waves from Cornwall in England to Newfoundland.
- 1902–1903: American physicist, mathematician, and inventor **John Stone** (1869–1943) used his knowledge of electric telegraphs to make important advances in radio tuning that helped overcome the problem of interference.
- 1906: Canadian-born engineer **Reginald Fessenden** (1866–1932) became the first person to transmit the human voice using radio waves. He sent a message 11 miles from a transmitter at Brant Rock, Massachusetts to ships with radio receivers in the Atlantic Ocean.
- 1906: American engineer **Lee De Forest** (1873–1961) invented the triode (audio) valve, an electronic component that makes radios smaller and more practical. This invention earned De Forest the nicknamed "the father of radio."
- 1910: First public radio broadcast made from the Metropolitan Opera, New York City.
- 1920s: Radio began to evolve into television.
- 1947: The invention of the transistor by **John Bardeen** (1908–1991), **Walter Brattain** (1902–1987), and **William Shockley** (1910–1989) of Bell Labs made it possible to amplify radio signals with much more compact circuits.
- 1954: The Regency TR-1, launched in October 1954, was the world's first commercially produced transistor radio. By the end of 1955, sales had reached 100,000.
- 1973: **Martin Cooper** of Motorola made the first ever telephone call by cellphone.
- 1981: German radio engineers began development of what's now called DAB (digital audio broadcasting) at the Institute für Rundfunktechnik in Munich.
- 1990: Radio experts came up with the original version of Wi-Fi (a way of connecting computers to one another and the Internet without wires).
- 1998: Bluetooth® (short-distance wireless communication for gadgets) was developed.

Annex II

References

https://www.youtube.com/watch?v=Ldnh0XlMVc0&list=RDLVdrLxfjqZHVo&index=11 (Radio waves)

https://www.cnn.com/2022/07/13/world/heartbeat-fast-radio-burst-scn/index.html

https://www.dummies.com/article/technology/electronics/circuitry/radio-electronics-transmitters-and-receivers-179838/ (book 1)

https://www.youtube.com/watch?v=drLxfjqZHVo (how do radio work)

https://www.youtube.com/watch?v=XYnlwiDaWKE (What a radio waves)

https://www.cnn.com/2022/07/13/world/heartbeat-fast-radio-burst-scn/index.html (News)

https://www.thomasnet.com/articles/automation-electronics/variable-capacitor-circuits/#:~:text=Unlike%20standard%20fixed%20capacitors%2C%20variable,the%20plates%20face%20one%20another. (Variable Capacitor)

https://www.explainthatstuff.com/antennas.html (Antennas and transmitters)

https://www.explainthatstuff.com/wirelessinternet.html (Wireless Internet)

Fun Book 1

Make: Electronics by Charles Platt. O'Reilly, 2015. A great starting point for kids who want to learn how to build things from electronic components.

Fun Book 2

Radio Rescue by Lynne Barasch, 2000. An illustrated (fictional) story book about a book who uses amateur (ham) radio to talk to people around the world.