Designing wireless transceivers: Walkie-Talkie and beyond

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Outline

- Wireless World
- Radio Communication Basics
- Modulation
- Design of Transceiver
Wireless World

- V-Day Scenario
- Communicating Without Wires
- Radio Communication Services
- Walkie-Talkie
- How it all begun?

Radio Communication Basics

- Modulation
- Design of Transceiver
V – Day Scenario

Speak

1m

Shout

10 m

Microphone - Loudspeaker

100 m

Transmitter - Receiver

1 km
Communicating without Wires

Radio Communication means any transmission, emission or reception of signs, signals, writing, images, sounds or intelligence of any nature by means of electromagnetic waves of frequencies 0Hz - 3000GHz propagated in space without artificial guide.
Radio Communication Services

Radio communication services

- Radio broadcasting
- TV broadcasting
- Satellite communication
- Mobile telephony
- Internet
- and more ....
A walkie-talkie is a hand-held portable, bi-directional radio transceiver. Major characteristics include a half-duplex channel (only one radio transmits at a time, though any number can listen) and a push-to-talk switch that starts transmission.

Hand-held transceivers became valuable communication tools for police, emergency services, and industrial and commercial users, and are also popular with some amateur radio operators.

The personal walkie-talkie has now become popular again with the new U.S. Family Radio Service and similar unlicensed services in other countries. While FRS walkie-talkies are also sometimes used as toys because mass-production makes them low cost, they have proper super heterodyne receivers and are a useful communication tool for both business and personal use.

The name **walkie talkie** was said to have been coined in 1941 during a demonstration in Toronto. A reporter saw a soldier walking about with the C-18 version strapped to his uniform. "What does it do?" the soldier was asked. "Well, you can talk with it while you walk with it," was the answer and the name Walkie Talkie was born.
How it all begun?

Donald Hings, pioneered one of the first Walkie-Talkies. In 1938 he was working for a mining company that deployed geologists to remote areas of western Canada to locate mineral deposits. Now, if there was a crash in the bush, pilots had no way of signalling their location. That year, he developed an effective, portable emergency voice radio. It could float, featured a folding antenna and its signal had a 130-mile range. The British Army was very impressed with these “radios” and as Mr. Hings continued his work to improve his invention, walkie talkies became invaluable war time tools.


The first radio receiver/transmitter to be nicknamed "Walkie-Talkie" was the backpacked Motorola SCR-300, created by an engineering team in 1940 at the Galvin Manufacturing Company (forerunner of Motorola). The team consisted of Dan Noble, who conceived of the design using FM technology, Henryk Magnuski who was the principal RF engineer, Bill Vogel, Lloyd Morris, and Marion Bond. Motorola produced the hand-held AM SCR-536 radio as well during the war. It was called the "Handie-Talkie" (HT).

In Sep. 2003 US manufacturers released the first application allowing a GSM to act like a walky-talky. In Nov. 2003 Nokia, provided the first push-to-talk (PTT) GSM, the Nokia 5140, displayed at left. According to a poll made on Aug. 2003 in the U.S.A by Zelos Group 45 % of them declared wishing that their next GSM is equipped with the PTT functionality. The Push-to-talk comes thus in second position behind the picturing functionality.
Wireless World

Radio Communication Basics

- E.M. Waves
- Radio Communication – Building Blocks
- Types of Communication
- Amplifier and Antenna Design

Modulation

Design of Transceivers
Electromagnetic waves are a form of radiated energy.

**Wavelength** \((\lambda)\) is the distance between a point on one wave and a similar point on the next wave (in meter).

**Time Period** \((T)\) is the time taken by the wave to travel one wavelength distance (in second).

**Velocity** of the wave \(\lambda / T = c\) (velocity of light, \(3 \times 10^8\) m/s).

**Frequency** \((f)\) is no. of wavelengths traveled in one second, \(f = 1 / T\).

Thus, \(\lambda \cdot f = c\) or, \(\lambda = c / f\).
Radio Commun. - Building Blocks

Block diagram of a radio communication system

- Basically, a radio communication system consists of a **transmitter**, a **channel**, and a **receiver**.

- In a transmitter,
  - The input sound signal is converted into equivalent electrical current / voltage by a transducer
  - The transducer output is amplified by a chain of amplifiers (so that it can travel longer distance)
  - The purpose of the transmit antenna is to efficiently transform the electrical signal into radiation energy

- In a receiver,
  - The receive antenna efficiently accepts the radiated energy and convert it to an electrical signal
  - As the signal suffered attenuation during travel it requires further amplification
  - The output transducer converts the electrical signal back into sound energy
Types of Communication

Simplex – A can talk to B
- Radio, T.V. broadcasting, CD/DVD ROM
- Simplest type, requires one transmitter and one receiver

Duplex – A and B both can talk to each other simultaneously
- Telephone, Telegraph
- Complex, requires two transmitter and two receiver at both ends
- Needs two different channels for simultaneous transmission

Block diagram of a radio communication system
Types of Communication (2)

Half-Duplex – A and B can both talk to each other but not simultaneously
- Fax, CD/DVD RW
- Needs one single channel for transmission
- Compromise between two, don’t require separate transmitter and receiver
- Same antenna and circuitry may be used for both transmission and reception

- A transceiver is a small unit that combines a transmitter and a receiver
- A small hand-held unit of transceiver is popularly called a walkie-talkie
- These units have 3 to 12 transistors, and 9-V battery is often used as a power supply
- The usual controls on the small transceivers unit are off-on switch with volume control, push-to-talk button, squelch control (eliminates background noise) and jack for earphones
Amplifier Design

- The radio transmitter makes it possible to send music and speech by means of radiated energy through the air.
- The radio station where the equipment is located for transmitting speech and music has a transducer, energy source, and antenna in the transmitter.
- The energy source powers the amplifiers.
**Antenna Design**

- **Antenna Dimension ~** $\lambda/2$

- For voice signal ($f \sim 3kHz$),
  
  $\lambda = \frac{c}{f} = \frac{(3 \times 10^8)}{(3 \times 10^3)}m = 10^5 m = 100 km$
  
  $d = \frac{\lambda}{2} = 50km!$

- Impossible to realize

- For Antenna dimension of $d = 50m$,
  
  $\lambda = 2d = 100 m$
  
  $f = \frac{c}{\lambda} = \frac{(3 \times 10^8)}{(100)m} = 3MHz!$

- Our vocal chords would burn
- Wireless World
- Radio Communication Basics
- Modulation
  - Modulation
  - Modulation Types
  - A.M. vs. F.M.
  - Carrier Frequency Bands
  - Managing Radio Spectrum
- Design of Transceivers
**Modulation** is the process of superimposing a signal (of relatively low frequency) on a high frequency signal (carrier wave), which is more suitable to transmit.

A modulator is a circuit that perform the modulation process, which is combining speech or music information with the carrier wave.

**Demodulation** is the opposite function of modulation, performed at the receiver side.
In the modulation process,

Firstly, a varying current is produced when sound waves strike a microphone.

Secondly, the microphone output is then fed into the modulator circuit where the audio and carrier waves are combined.
Modulation Types

- **Modulation**
  - **Analog**
    - Continuous Wave (CW)
      1. Amplitude Modulation (AM)
      2. Frequency Modulation (FM)
      3. Phase Modulation (PM)
  - **Digital**
    - Continuous Wave (CW)
      1. Amplitude Shift Keying (ASK)
      2. Phase Shift Keying (PSK)
      3. Frequency Shift Keying (FSK)
    - Pulse
      1. Pulse Code Modulation (PCM)
      2. Differential PCM (DPCM)
      3. Delta Modulation (DM)
    - Pulse
      1. Pulse Amplitude Modulation (PAM)
      2. Pulse Width Modulation (PWM)
      3. Pulse Position Modulation (PPM)
Modulation Types

In the AM process, the alternating current (AC) from the microphone modulates the carrier wave by causing carrier wave’s amplitude or strength to rise and fall.

In the FM process, the alternating current (AC) from the microphone modulates the carrier wave by changing carrier wave’s frequency.
Advantage of FM over AM

- Automobile ignition systems, lightning, and switching actions can produce a noise commonly called **static**. AM waves don’t have constant envelopes and therefore more affected by static than FM. Unwanted electromagnetic waves do not cause the frequency of FM carrier wave to change.

- Non-linear amplifiers may be used

- Constant bandwidth system

- Exchange of bandwidth with signal-to-noise-ratio

- Stereophonic reception is viable in FM

- Frequency reuse possible due to limited coverage

In FM, the audio signals cause the FM carrier signal to change frequency above and below assigned center frequency.

In FM, the amplitude of the audio signal is proportional to the amount of frequency shift above and below the carrier frequency.
The carrier waves frequencies for radio broadcasting are assigned by **Federal Communications Commission (FCC)**.

- **AM carrier frequency** - 535 kHz to 1605 kHz
- **FM carrier frequency** - 87.5 MHz to 108 MHz

<table>
<thead>
<tr>
<th>Name</th>
<th>Frequency Range</th>
<th>Wave Length</th>
<th>Application</th>
<th>Propagation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELF</td>
<td>300Hz to 3kHz</td>
<td>100 km to 1000km</td>
<td>Navigation, long distance communication with ships</td>
<td>Wave tube between earth surface and the ionosphere</td>
</tr>
<tr>
<td>VLF</td>
<td>3kHz to 30kHz</td>
<td>10km to 100km</td>
<td>Navigation, long distance communication</td>
<td>Ground propagation, stable</td>
</tr>
<tr>
<td>LF</td>
<td>30kHz to 300kHz</td>
<td>1km to 10km</td>
<td>Navigation, long distance communication with ships</td>
<td>Ground propagation, stable</td>
</tr>
<tr>
<td>MF</td>
<td>300kHz to 3MHz</td>
<td>100m to 1km</td>
<td>AM broadcasting, radio navigation</td>
<td>Ground-wave, sky-wave propagation. Fading</td>
</tr>
<tr>
<td>HF</td>
<td>3MHz to 30MHz</td>
<td>10m to 100m</td>
<td>Radio broadcasting, fixed point-to-point (around the world)</td>
<td>Large perturbation, reflection in ionosphere</td>
</tr>
<tr>
<td>VHF</td>
<td>30MHz to 300MHz</td>
<td>1m to 10m</td>
<td>Radio and TV broadcasting, mobile services</td>
<td>Diffraction</td>
</tr>
<tr>
<td>UHF</td>
<td>300MHz to 3GHz</td>
<td>10cm to 100cm</td>
<td>Cellular telephony (GSM, NMT, AMPS), digital TV, fixed point-to-point, satellite, radar</td>
<td>Shadowing by mountains and buildings</td>
</tr>
<tr>
<td>SHF</td>
<td>3GHz to 30GHz</td>
<td>1cm to 10cm</td>
<td>Broadband indoor systems, microwave links, satellite communications</td>
<td>Attenuation due to rain, snow and fog</td>
</tr>
<tr>
<td>EHF</td>
<td>30GHz to 300GHz</td>
<td>1mm to 10mm</td>
<td>LOS communication (short distance or satellite)</td>
<td>Attenuation due to rain, snow and gases</td>
</tr>
</tbody>
</table>
Managing Radio Spectrum

- The frequency spectrum is common to all radio systems, so all radio frequencies are regulated in order to avoid interference.
- Radio propagation does not recognize geo-politic boundaries.
- Propagation in different parts of the radio spectrum has different characteristics.
- International cooperation and regulations are required for an orderly worldwide use of the radio spectrum.

The International Telecommunication Union (ITU) is an agency part of the United Nations that takes care of managing radio spectrum worldwide. With 184 membership countries, the ITU main activities are:

- Frequency assignment
- Standardization
- Research
- System compatibility issues
- Coordination and planning of the international telecomm services

Weblink: [www.itu.int](http://www.itu.int)
- Wireless World
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- Modulation
- Design of Transceivers
  - Let’s Get Our Hands Dirty!
  - Before We Proceed Further
  - Coil-Less F.M. Transmitter
  - Component List
  - Long-Range F.M. Transmitter
Let’s get our hands dirty!

Input fed at base of BC548

Removing feedback

Power Supply from battery

Short Circuit protection

FM Transmitter

Transducer (Microphone)

Amplifier

Modulator

Tuned oscillator

CE mode Voltage divider bias
Before we Proceed Further

- Take care with transmitter circuits. It is illegal in most countries to operate radio transmitters without a license.
- The simple circuits are for educational demonstration with a range of 10-100m.
- It is better to use transistors compatible with RF frequencies (BC548 is not strictly a RF transistor).
- It is very difficult to build a coil (inductor). The previous circuit consists of 7 turns on a quarter inch plastic former with a tuning slug. The tuning slug is adjusted to tune the transmitter. Actual range of the prototype tuned from 70MHz to around 120MHz.
- The aerial is a few inches of wire. TV aerials and Yagi-Uda antenna may increase the range further.
- Although RF circuits are best constructed on a PCB, you can get away with Vero board, keep all leads short, and break tracks at appropriate points.
- Don’t hold the circuit in your hand and try to speak. Body capacitance is equivalent to a 200pF capacitor shunted to earth, damping all oscillations.

Some useful links:
www.newcircuits.com/
www.electronic-circuits-diagrams.com/
www.kingsolder.com/
www.electronicsinfoline.com/Projects/Electronics/
The RF oscillator using the inverter N2 and 10.7Mhz ceramic filter is driving the parallel combination of N4 to N6 through N3. Since these inverters are in parallel the output impedance will be low so that it can directly drive an aerial of 1/4th wavelength. Since the output of N4-N6 is square wave there will be a lot of harmonics in it.

The 9th harmonics of 10.7Mhz (96.3Mhz) will hence be at the center of the FM band. N1 is working as an audio amplifier. The audio signals from the microphone are amplified and fed to the vvaricap diode. The signal varies the capacitance of the vvaricap and hence varies the oscillator frequency which produce Frequency Modulation.
# Component List

<table>
<thead>
<tr>
<th>Component</th>
<th>No. of units required</th>
<th>Price per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FM Transmitter (2 Sets)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC 4069</td>
<td>1</td>
<td>20/-</td>
</tr>
<tr>
<td>BB109 Varicap</td>
<td>1</td>
<td>10/-</td>
</tr>
<tr>
<td>Condenser Mic</td>
<td>1</td>
<td>20/-</td>
</tr>
<tr>
<td>Resistors</td>
<td>6</td>
<td>2/-</td>
</tr>
<tr>
<td>Capacitors</td>
<td>6</td>
<td>3/-</td>
</tr>
<tr>
<td>10.7 MHz ceramic crystal filter</td>
<td>1</td>
<td>10/-</td>
</tr>
<tr>
<td><strong>FM Receiver (2 Sets)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional FM receiver board</td>
<td>1</td>
<td>50/-</td>
</tr>
<tr>
<td>TBA 820 Amplifier Board</td>
<td>1</td>
<td>10/-</td>
</tr>
<tr>
<td>Speaker 8 ohms small size</td>
<td>1</td>
<td>10/-</td>
</tr>
<tr>
<td><strong>Common Parts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antenna TV aerial</td>
<td>1</td>
<td>10/-</td>
</tr>
<tr>
<td>DPDT Switch</td>
<td>1</td>
<td>3/-</td>
</tr>
<tr>
<td>Power Supply 9V Battery</td>
<td>1</td>
<td>15/-</td>
</tr>
</tbody>
</table>

![FM Receiver Amplifier Board](image)
Assemble the circuit on a glass epoxy board and house the transmitter inside an Al case. Shield the oscillator stage using an Al sheet.

VR1 Pot is used to vary the fundamental frequency (near 100 MHz), VR2 Pot is used as power control. For hum-free operation, use a 12V (10 x 1.2V) rechargeable battery pack of Ni-Cd cells. Transistor T2 must be mounted on a heat sink. Do not switch on the transmitter without a matching antenna. Adjust both trimmers (VC1 and VC2) for maximum transmission power.
Questions???
Thank You!