Antenna Design for Portable Devices

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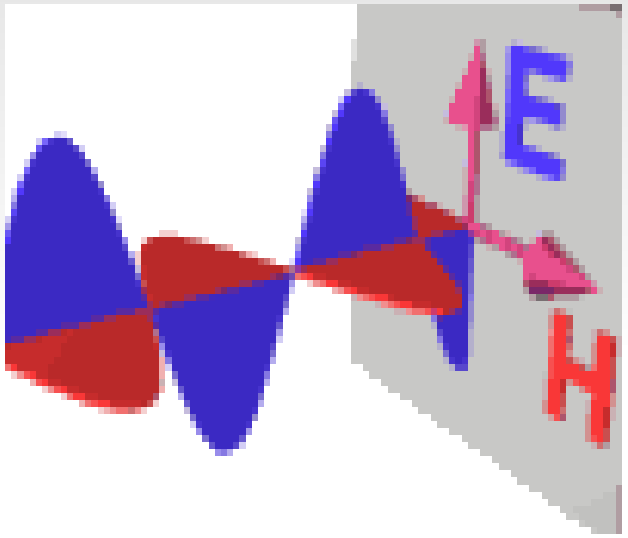
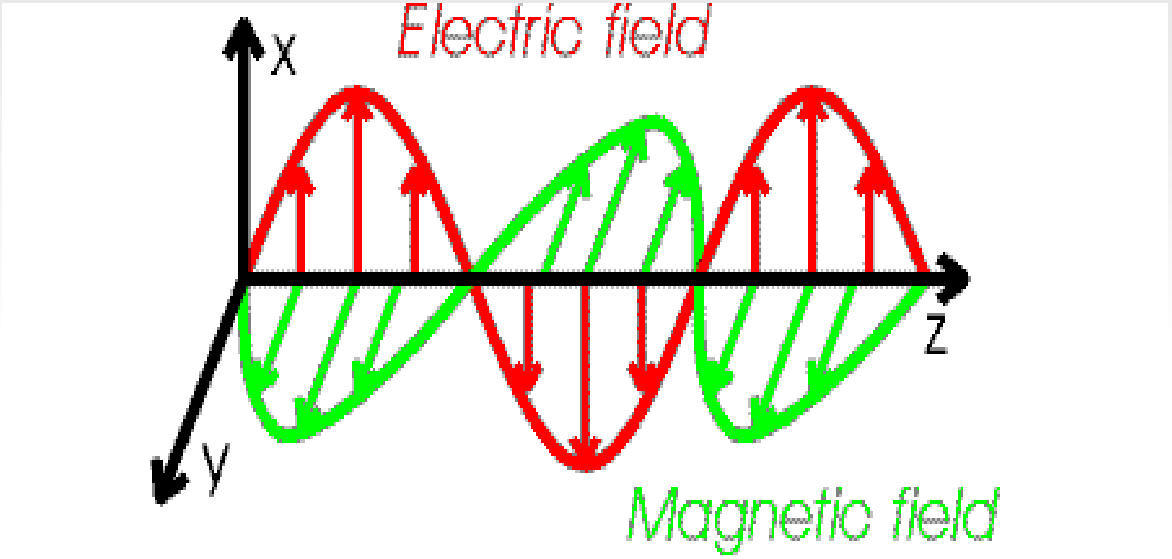
Introduction

- Part 1: Antennas
- Part 2: Antennas for Portable Devices
- Part 3: Questions & Answers

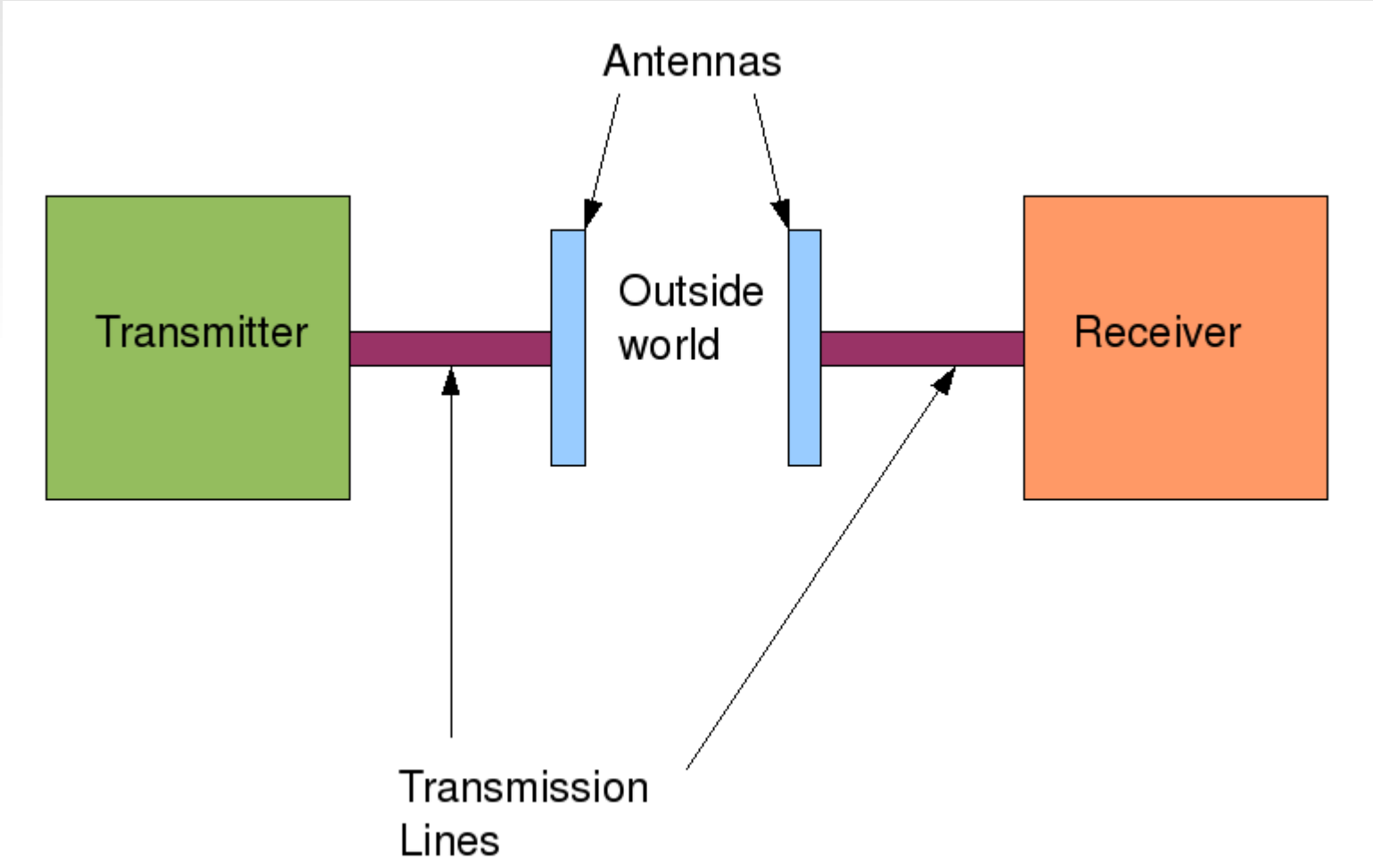
Radio



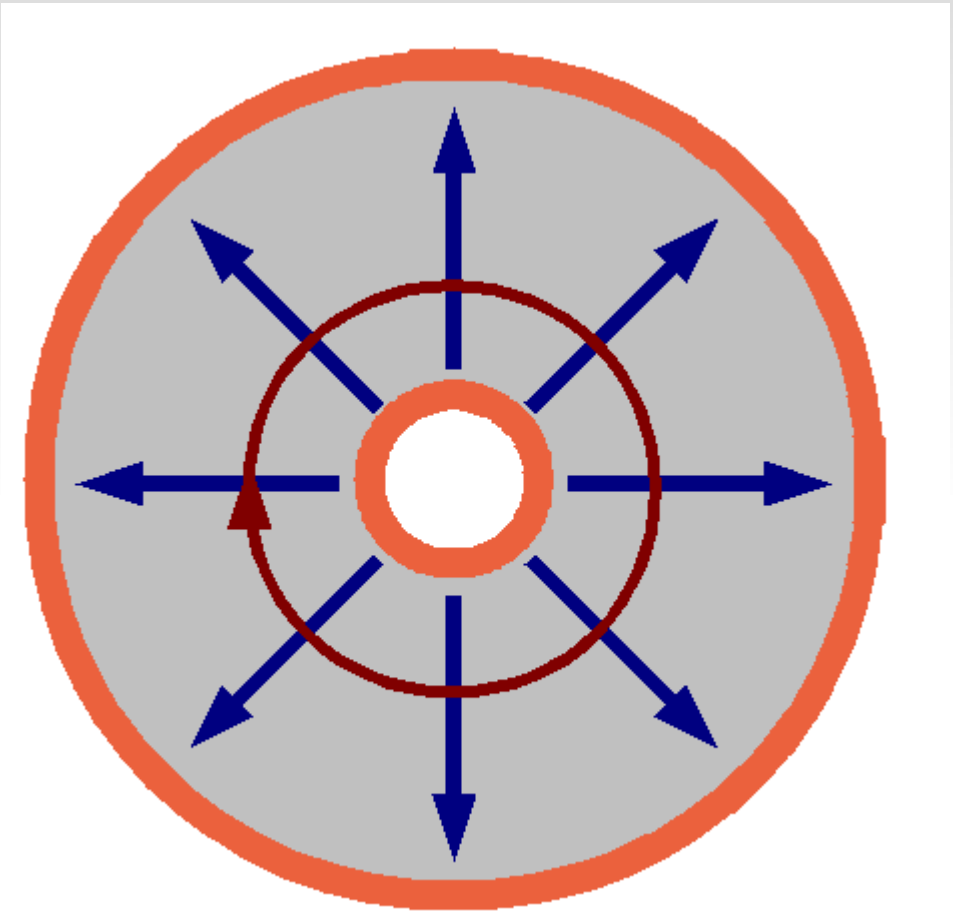


- Animations from www.physicsanimations.com and Prof.Cesar Bruma

Radio Systems



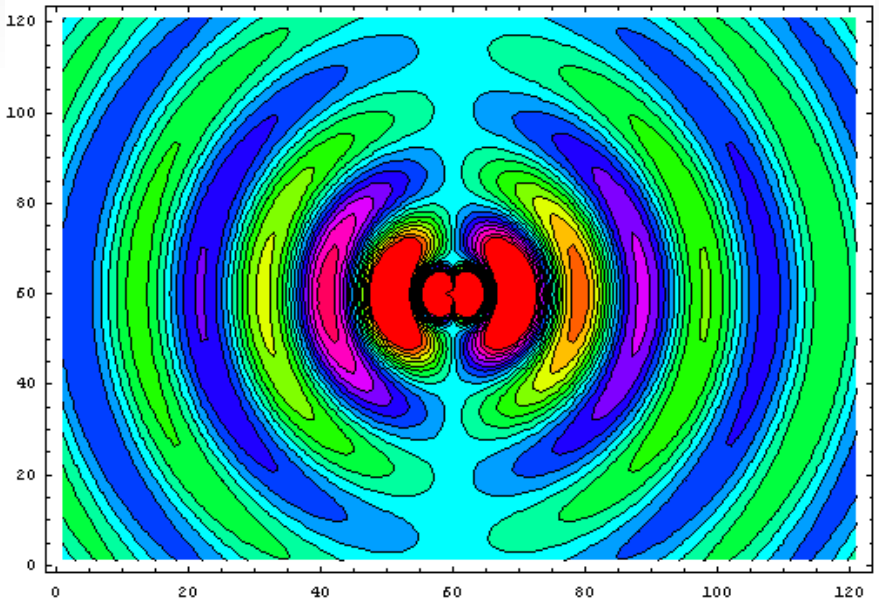
Transmission lines

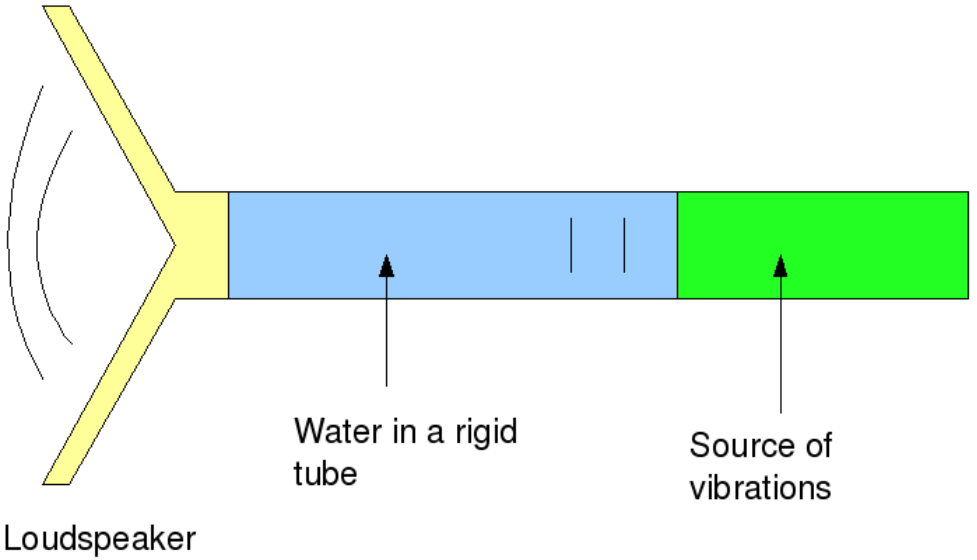


- Blue is electric field, red is magnetic field
- Notice fields are still 90 deg to each other

The Antenna

- Dipole animation from wikimedia.org



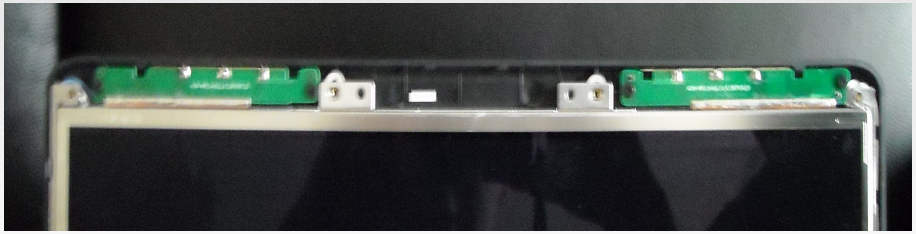


Antenna Engineering

- The conversion must be efficient.
  - Power coming from the transmission line must go into the antenna.
    - Not back down the transmission line.
  - Power coming into the antenna must go into space.
    - Not converted into heat.
- Different patterns of power are possible.
  - Directional and Omni- directional antennas.
- Objects close to the antenna affect it.
- Antennas and TX lines need to be small and cheap.

Part 2: Antennas for Portable Devices

- Antennas are generally different for each notebook and mobile phone.
- There are 6 or 7 antennas in some notebooks.



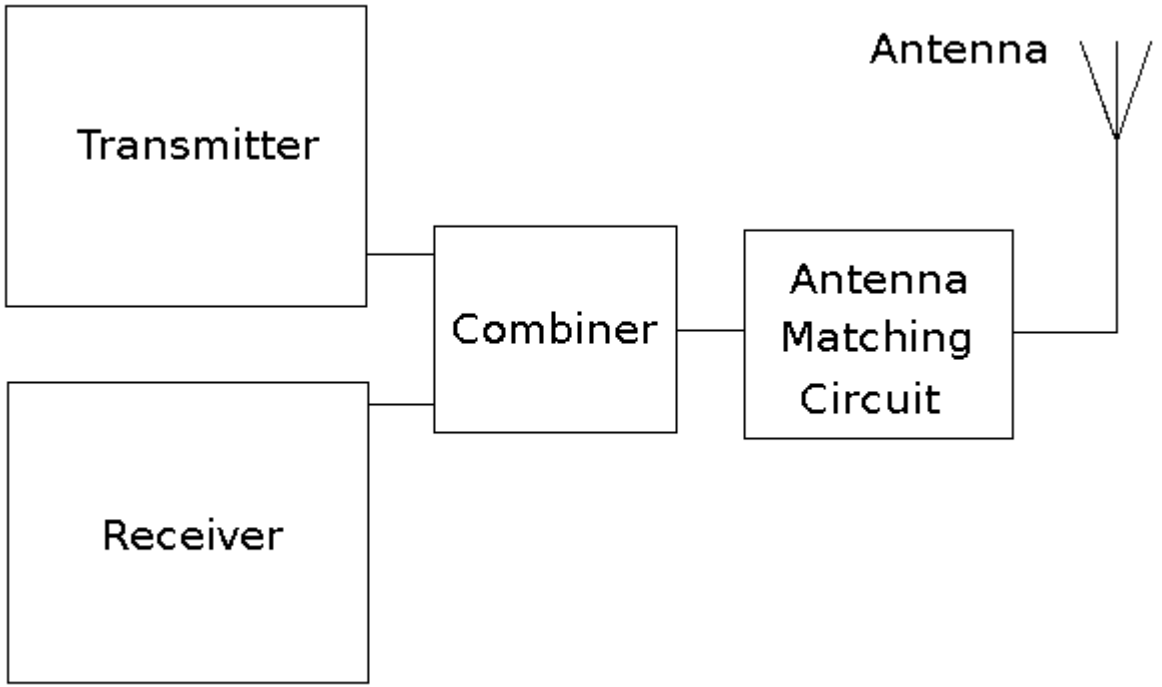
What I do

- I look after the things I mentioned in the last two slides.
- I design antennas.
- I specify antennas, arrange their layout.
- I specify aspects of the radios.
- I work on interference.
- I check all the above, with the internal lab, labs at other sites and vendor's labs.
- Report on problems, help with strategy.

The Design Process

- 1. A placement is designated for the antenna.
- 2. A specification is given.
- 3. The designers comes up with a set of designs they want to try.
- 4. Those designs are either:
  - Simulated using electromagnetic software.
  - Or, prototyped and measured using antenna measurement equipment.
  - The simulation and prototypes include a mock- up of the surrounding devices. The real device is used if it's available.
  - A matching circuit is designed.
- 5. The design and matching circuit are refined.
- 6. The design is made manufacturable.
- 7. The design is embedded in the prototype product and it's performance is measured.
- 8. The antenna and device goes into mass production.

What Type of System is Used?



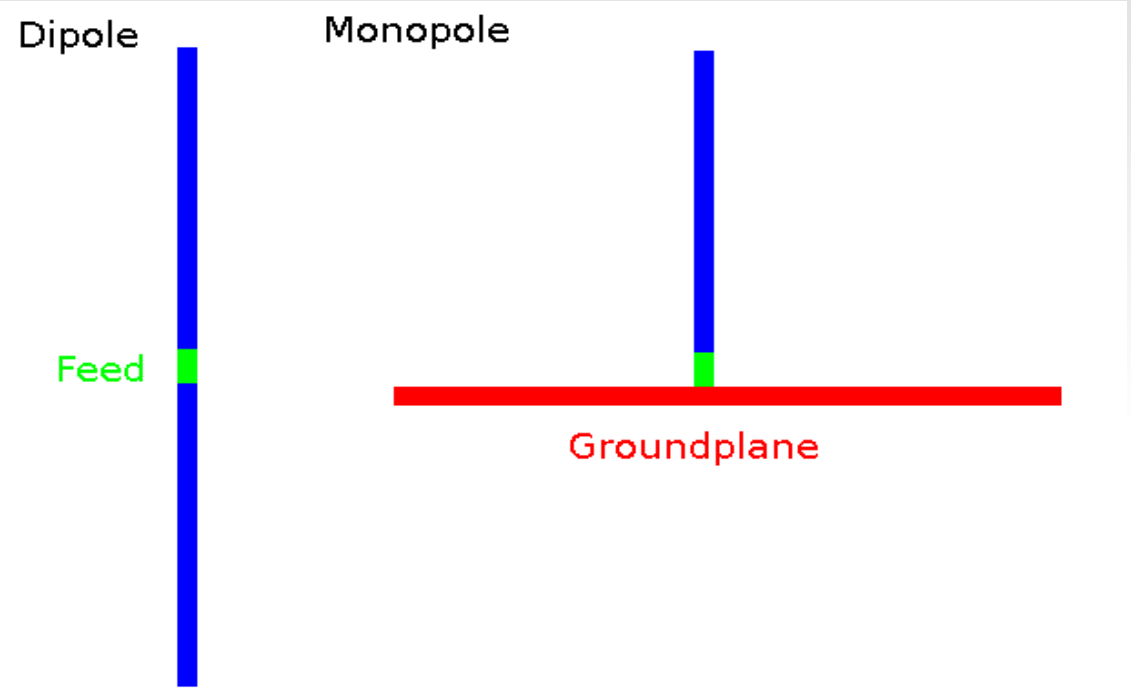
All interconnections are microstrip or coax cables

What Type of Antennas are Used?

- Monopole types
  - Monopole
  - Normal- mode helical antenna
  - Meander
  - Inverted- F antenna
  - Dielectrically- loaded monopoles
- Microstrip types
  - Planar Inverted- F antenna (PIFA)
- There is controversy over naming of these antennas, and in some cases controversy over how they work.
- PIFA antennas are probably the most common now.

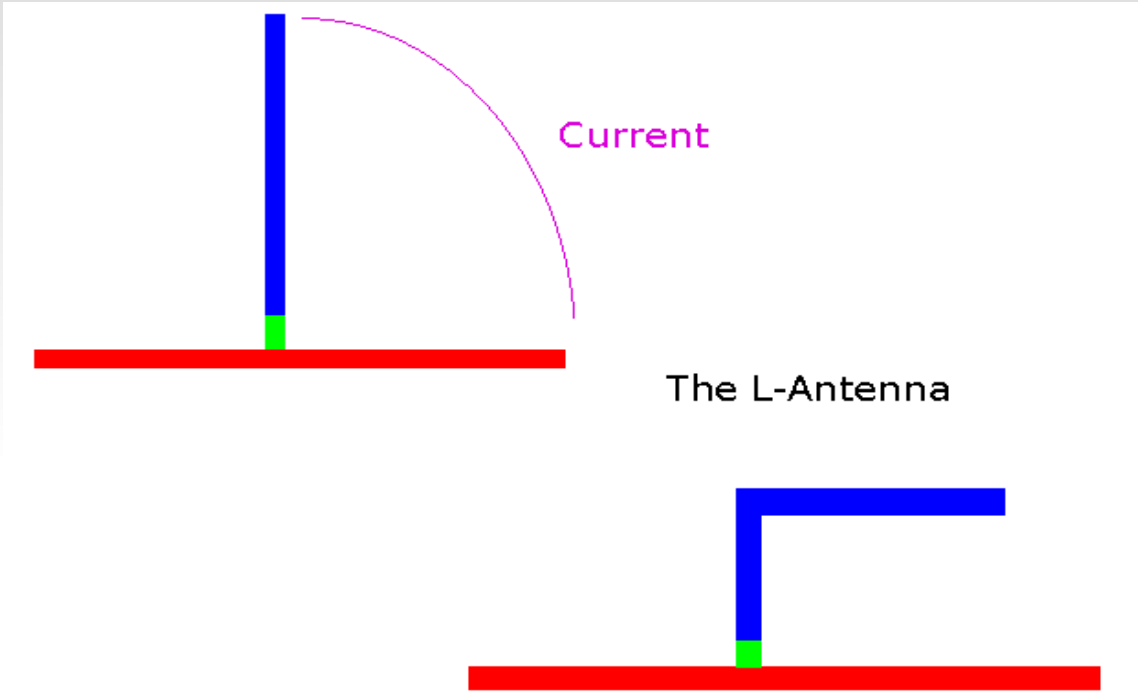
The Monopole Antenna

- Omnidirectional radiation pattern.
- Vertically polarized - polarised in the direction of the wire.
- High current at the base.
- Current decreases along the conductor to zero at the end.
- Analogous a vibrating string on a musical instrument.
- Ground plane is a mirror, but only if it is flat and directly below the antenna.



Monopole shortening

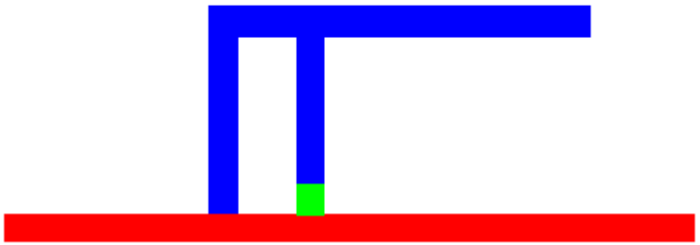
- Monopole antennas are too long for many applications.
- From the point of view of radiation the bottom of the monopole is more important than the top because more current flows at the bottom.
  - So, we compromise the top in some way.
  - We can bend it towards the groundplane. If it's bent then the input impedance will change. Some power will come out in the horizontal polarisation. But it'll work.



The Inverted-F antenna

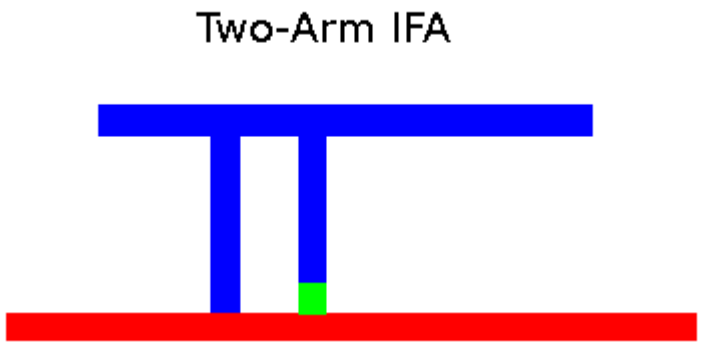
- It happens that the matching circuit we need to make an L- antenna work well is a low- value inductor connected between the feed and ground.
  - We can build this matching circuit straight into the antenna.
- If the antennas is made from thick conductors then resistance is decreased.
  - Thick conductors also improve bandwidth.
- So, we have the F or Inverted- F antenna which is used in most notebook computers for WLAN. It has many other uses too.

The F-Antenna



Multi-band Inverted-F antennas

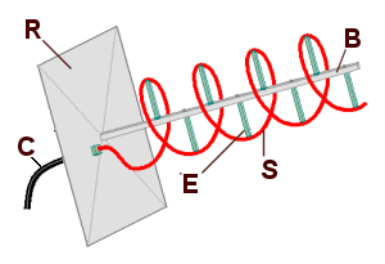
- More branches can be added to the antenna to support different bands.
- However, each band changes the impedance of the others. The matching circuit must be a compromise between the requirements of them all.
  - So, performance generally deteriorates as more bands are required.



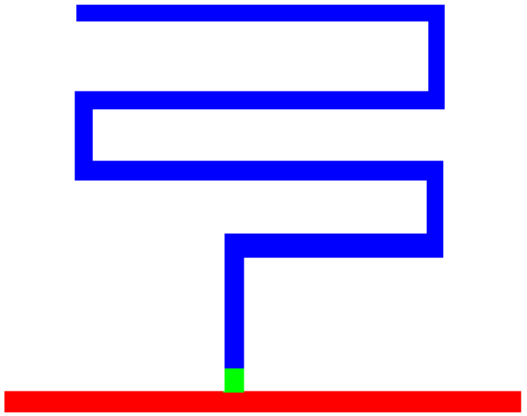
Other Monopole Variants

- Normal- Mode Helix
  - Bend the monopole into a coil shape.
  - Used for “stubby” antennas on mobile phones.
- Meander Antenna
  - Make the monopole into a wavy line. A flat version of a helix.
  - Sometimes used on Bluetooth modules.

- Helix from Wikipedia commons

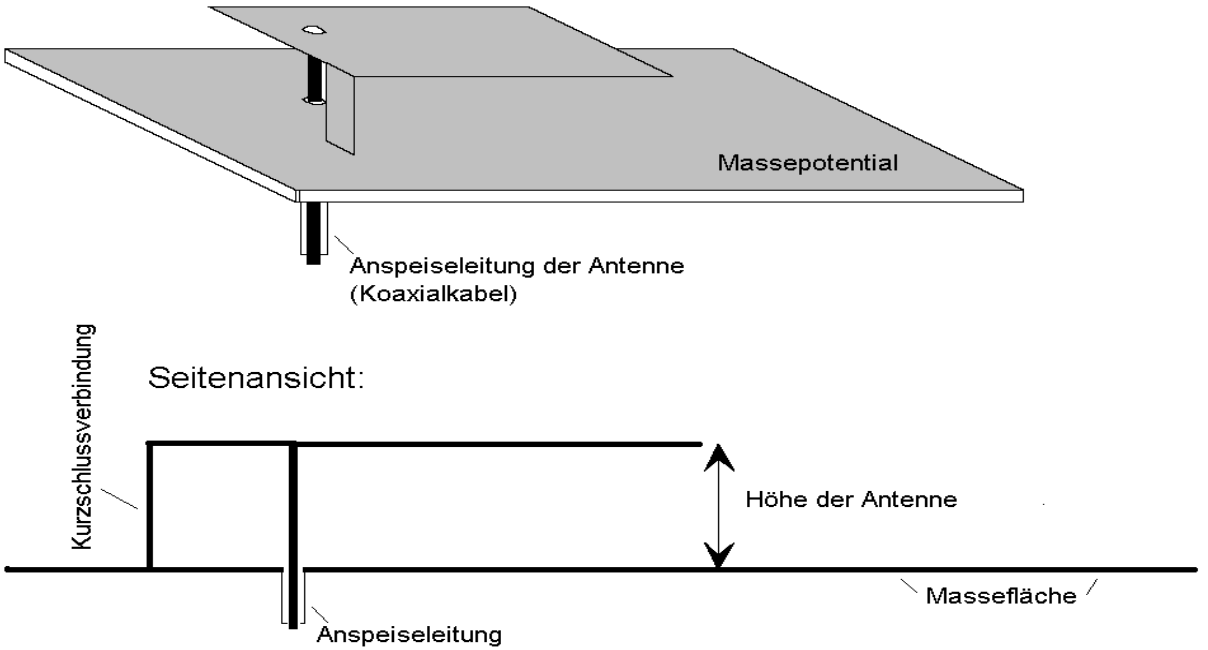


Meander Antenna



The Planar Inverted-F Antenna (PIFA)

- This is the antenna that is probably in your mobile phone.
- Prepare to be confused...
  - The name PIFA is very similar to IFA, indicating that both are similar. Some antenna people think that they are.
  - Most antenna folks, including me, think that PIFAs work in a different way.
  - Picture from wikimedia commons



The PIFA

- The best theory I have found to explain PIFAs is to compare them to slot antennas.
- The gap between the sides of the antenna and the groundplane forms a slot.
- This theory is still quite speculative. Many people doing work on PIFAs don't give much explanation about them.
  - Much work is done by simulation and prototyping without attempt to understand or form a model of the antenna.
- The Patch antennas used in base- stations can be modeled at types of slot antenna too.

Slot Antennas and PIFAs

- A slot antenna is a slot cut in a conductor.
- It is a resonator made out of slotline.
  - But it's a leaky resonator, so it's an antenna.
- Can be analysed as the "dual" of a dipole using Babinet's principle.
- In a PIFA the slots are the gaps between the PIFA and the groundplane below.

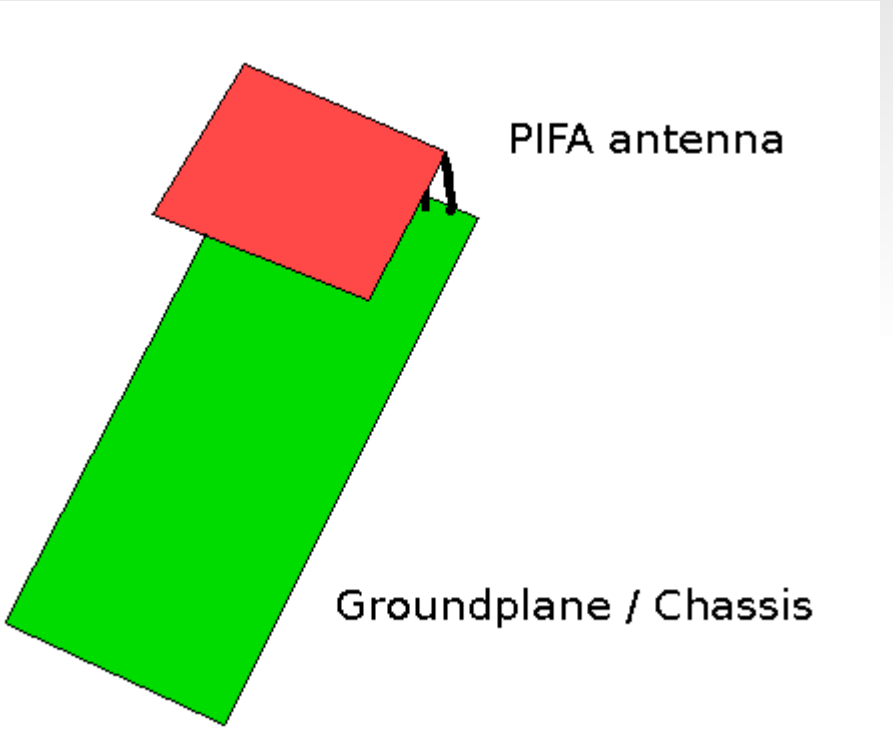
- Picture from wikimedia commons

Groundplane Effects

- In classical antenna theory the groundplane is always below the antenna, and always very large.
- In notebook computers the groundplane is to the side of the antenna, parallel with it.
- In handsets the groundplane is below the antenna, but the groundplane is small.
- Both of these facts are beneficials
  - It turns out that an antenna mounted parallel with the groundplane has more bandwidth
  - The small groundplane of a handset antenna also works better than a larger one, unless it's very small.

Groundplane Effects on Handsets

- What does the groundplane of a handset look like?
  - It is a dipole antenna with very, very thick conductors
  - A dipole like this is called a “fat” dipole, they are used in other applications.
  - So, what we have is a PIFA on a fat dipole formed by the groundplane.
  - The fat dipole re- radiates and broadens the bandwidth.



Device Problems

- Handset designers and Notebook designers don't know about antennas.
  - As a result they often create designs that cause problems for the antennas.
- Typical problems
  - Circuits are sensitive to currents from the antenna.
  - Circuits transmit and this is picked up by the antenna. Both this and the previous problem is normally caused by poor shielding.
  - Components re- radiate
  - Components absorb radiation
  - Components are resistors to groundplane current.
    - This is the biggest problem.
- To mitigate these problems antenna designers do a lot of work on other parts of the handset introducing short circuits in the right places.

Concluding Remarks

- Antenna design is a mixture of experimentation, science and experience.
- The antenna designer must know lots about matching circuits, transmission lines, radios, materials, radio propagation and antenna measurement.
- The area still hasn't being properly systematised – unlike the situation in larger antennas.

Any Questions?