Class 4
Ham Radio General Supplement

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The Three Changeable Things

- Amplitude
- Frequency
- Phase

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“Codes and Modes”

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Modes of Communication

- On/Off (CW)
- Analog Voice
- Analog Image
- Digital Voice
- Text and Data

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Morse Code

- Continuous wave (CW)
- Modulated continuous wave (MCW)
- Frequency shifting continuous wave

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Analog Voice

- Amplitude modulation (AM)
- Double-sideband suppressed carrier (DSB-SC)
- Independent sideband (ISB)
- Single sideband (SSB)
- Compatible sideband transmission (AME)
- Frequency modulation (FM)
- Phase modulation (PM)

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Digital Voice

- APCO P25
- D-STAR (AMBE over GMSK)
- DMR (FSK modulation variant with TDMA)
- System Fusion (AMBE CODEC with C4FM)
- FreeDV (PSK)
- M17 (Codec2 with 4FSK)

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Image

- Amateur television (ATV)
- Slow-scan television (SSTV)
- Facsimile

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Text and Data

- Amateur teleprinting over radio (AMTOR)
- D-STAR (128 kbit/s), data-only mode)
- Hellschreiber, a facsimile-based teleprinter
- Discrete multi-tone modulation (MT63 and others)
- Multiple frequency-shift keying (MFSK)
  - FSK441, JT6M, JT65, and FT8
  - Olivia MFSK
  - JS8

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More Text and Data

- Packet Radio (AX25)
  - AMPRNet
  - APRS
- PACTOR (AMTOR + packet radio)
- Radioteletype (RTTY) (FSK)
- Multimedia over 802.11
- Spreadspectrum

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One More Time

- Phase-shift keying:
  - PSK31: 31 baud binary PSK
  - QPSK31: 31 baud quadrature PSK
  - PSK63: 63 baud binary PSK
  - QPSK63: 63 baud quadrature PSK

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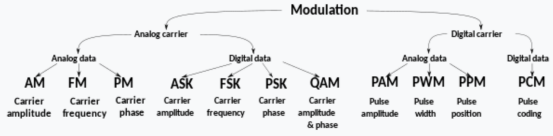
A Family Tree

Passband modulation



Analog modulation

AM · FM · PM · QAM · SM · SSB

Digital modulation

ASK · APSK · CPM · FSK · MFSK · MSK · OOK · PPM · PSK · QAM · SC-FDE · TCM · WDM

Hierarchical modulation

QAM · WDM

Spread spectrum

CSS · DSSS · FHSS · THSS

See also

Capacity-approaching codes · Demodulation · Line coding · Modem · AnM · PoM · PAM · PCM · PDM · PWM · ΔΣM · **OFDM** · FDM · Multiplexing

V · T · E

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Revisiting Antennas

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Every antenna has a current flowing in it

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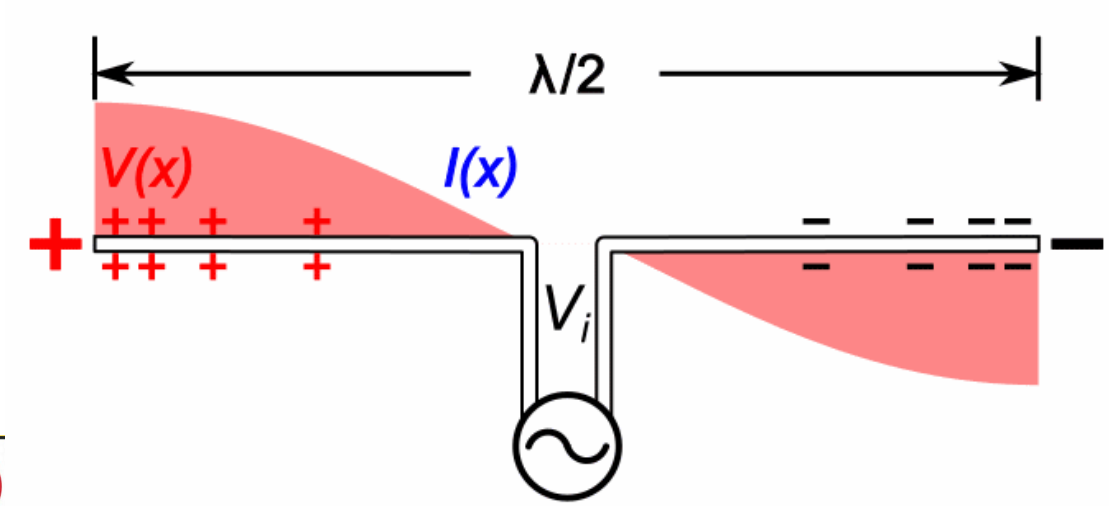
Dipole antenna



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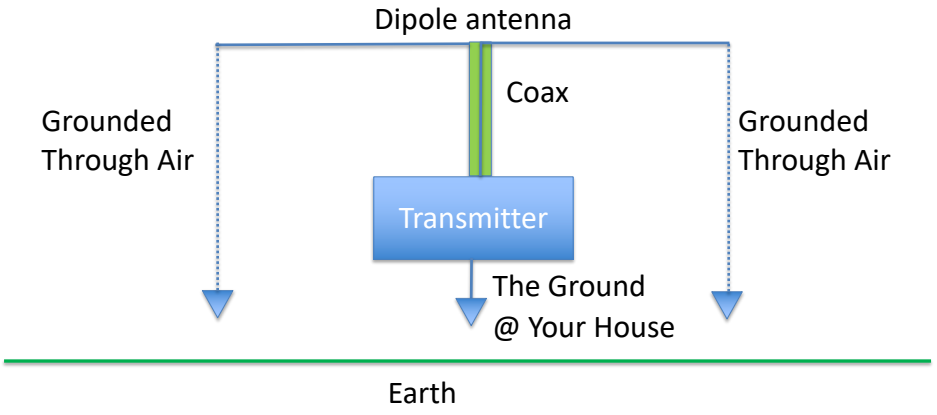
Where's the circuit?



Advanced Topic:
Is this also true for ladder line?

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Is a monopole antenna even possible?

- No current flow...
  => no changing EM field
  => no radiation
  => not an antenna!

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So how does your HT work?

- Back to those “unintended circuits”

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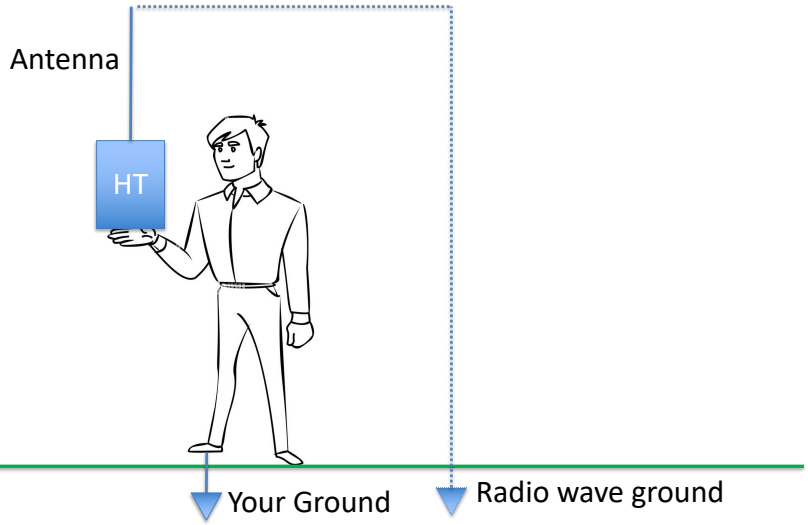
Your HT: "You complete me"



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Scary Stuff!

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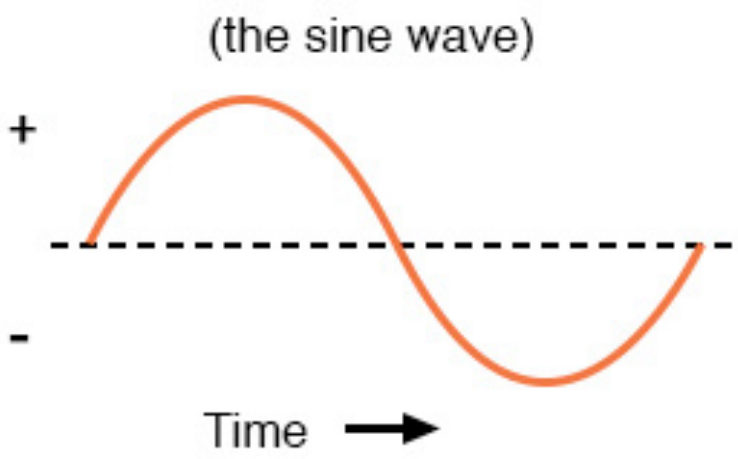
Why is this called a sine wave?



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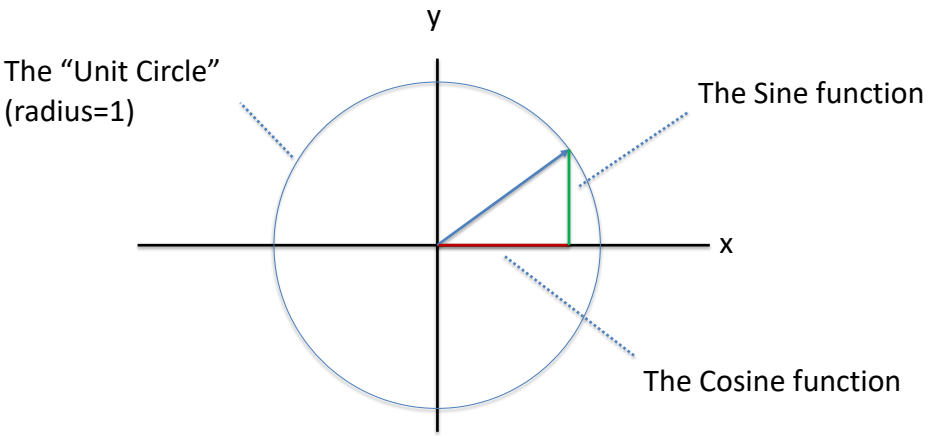
Back to High School



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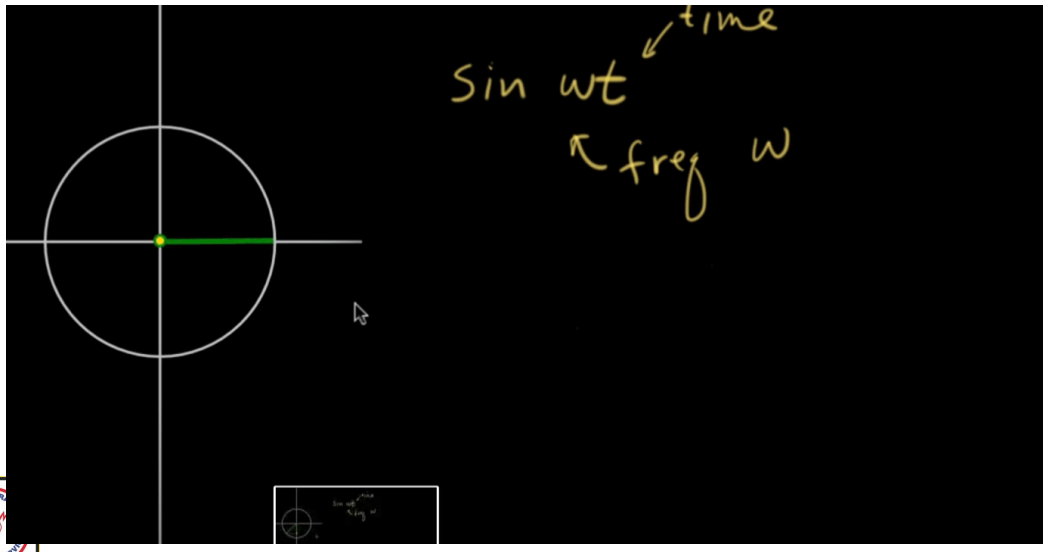
The wave is the function!



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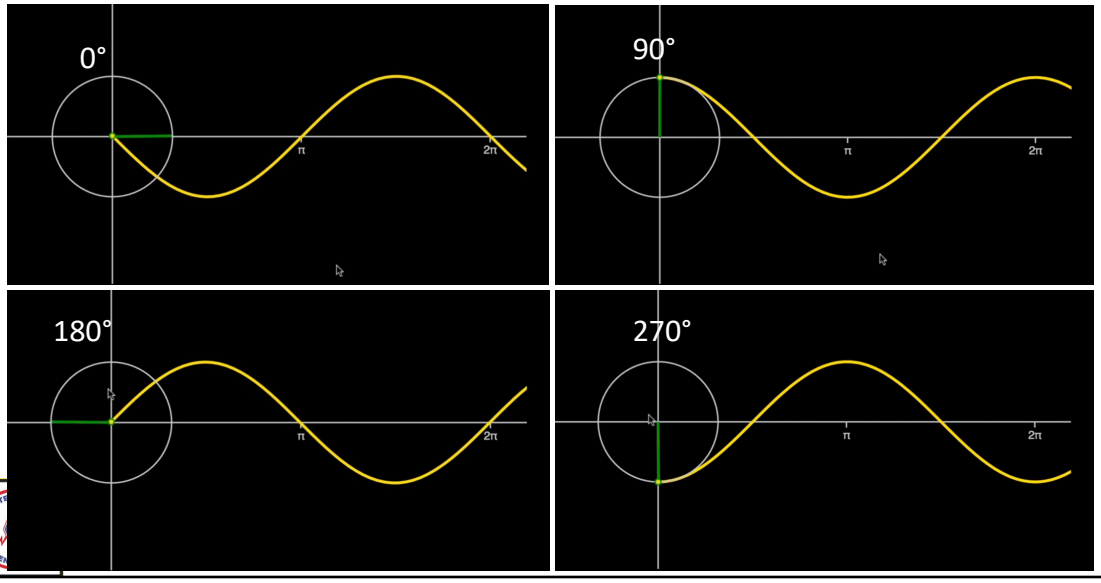
Now you can see the "phase" angle



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Adding Sine waves

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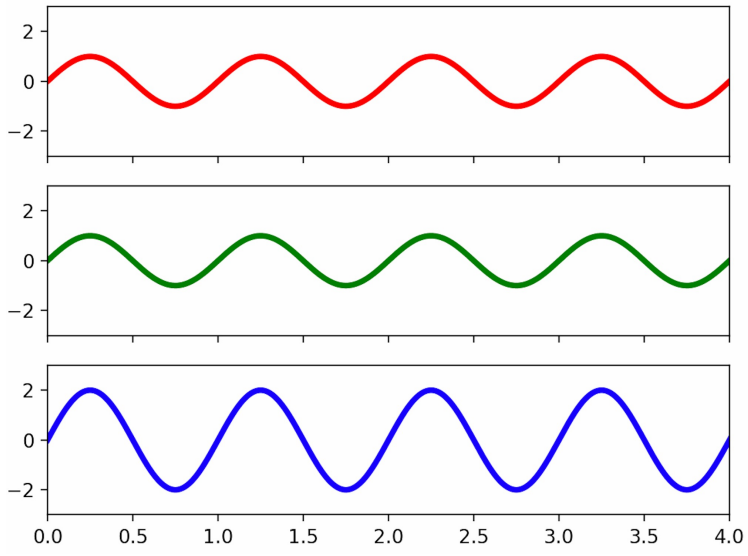
Equal frequency waves in phase



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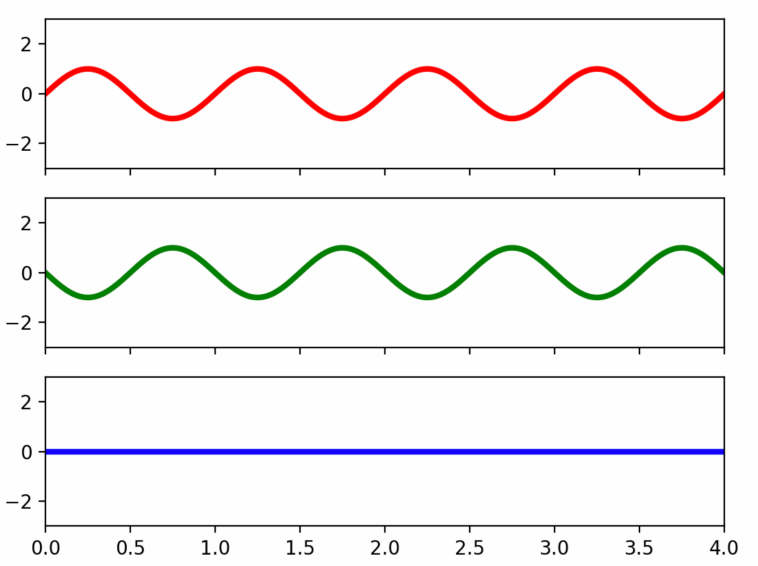
Equal frequency waves 180° out of phase



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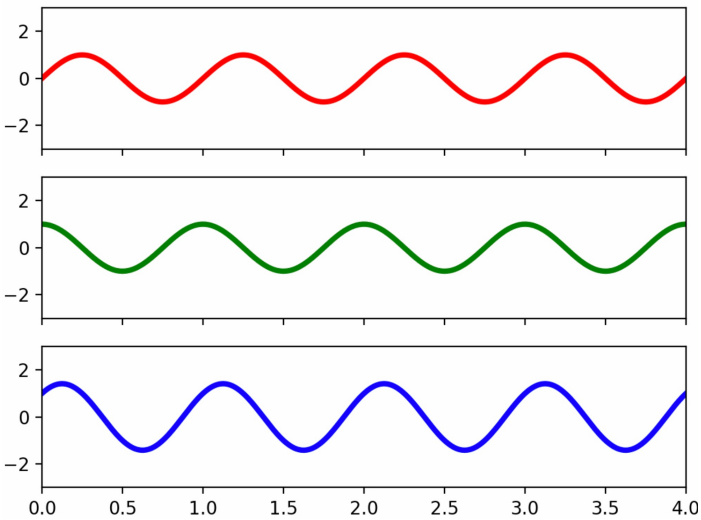
Equal frequency waves 90° out of phase



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Now we can do Complex Numbers

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Complex numbers made simple

- Example complex number 5+j3
- Resistive and reactive components (sorta)
- There is nothing ‘imaginary’ about the imaginary part
- It’s just the phase angle

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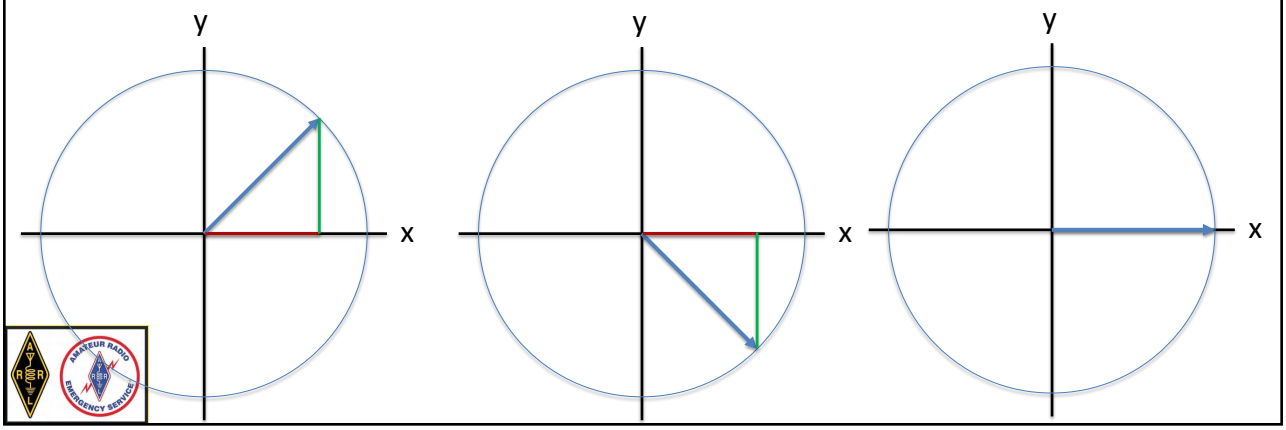
Complex addition – also made simple!

3 + 3j + 3 – 3j = 6 + 0j



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What can we do with [simple] complex numbers?

- Impedance is complex resistance
- Resisters have no imaginary value – so no phase shift
- Coils and capacitors do
- Pretty much all circuits have coils and capacitors (especially radio!)
- So we always have mismatches

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Is this a problem?

- V and I are out of phase
- Ohm's law still holds at every moment in time

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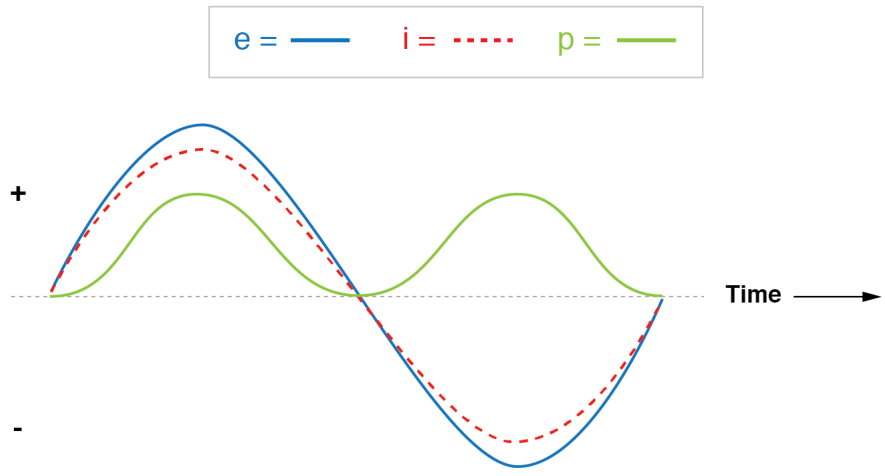
Purely resistive load



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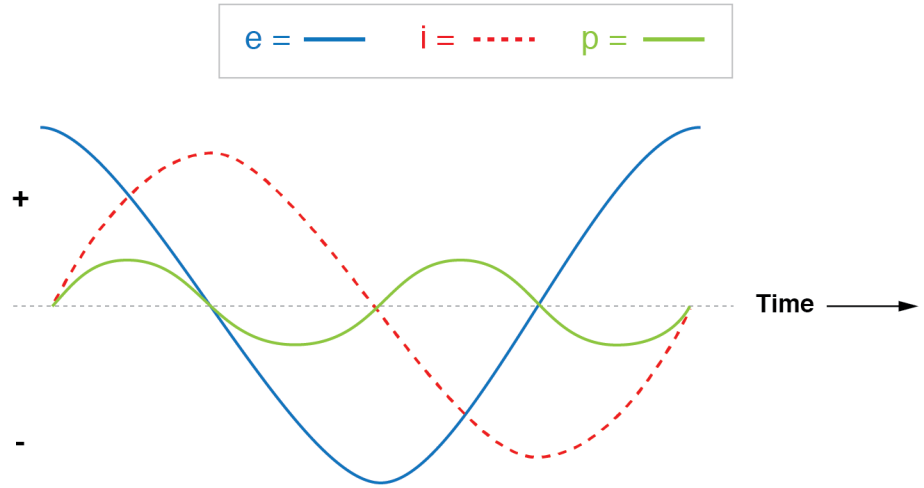
Purely *reactive* load



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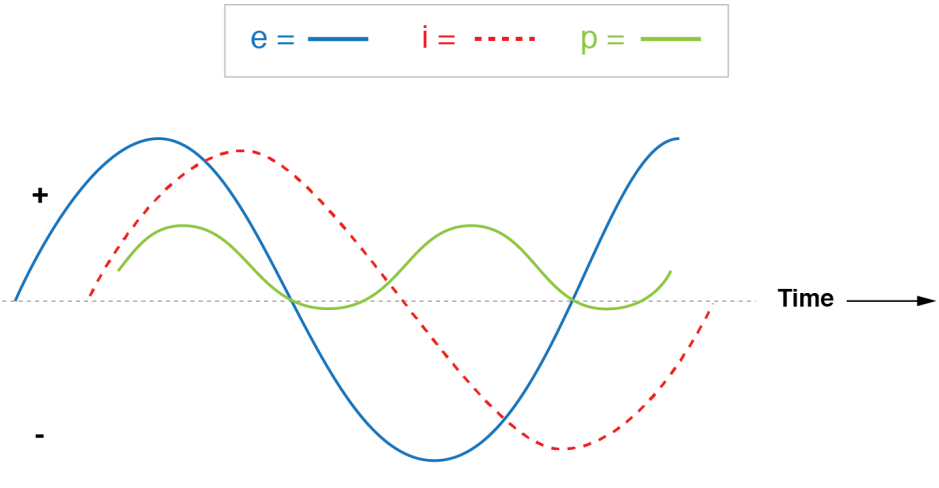
Resistive and reactive



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Not all the power gets into the antenna

- But all the power has to go somewhere, so some gets reflected back into your transmitter
- In fact, it reflects back and forth over and over on your feed line

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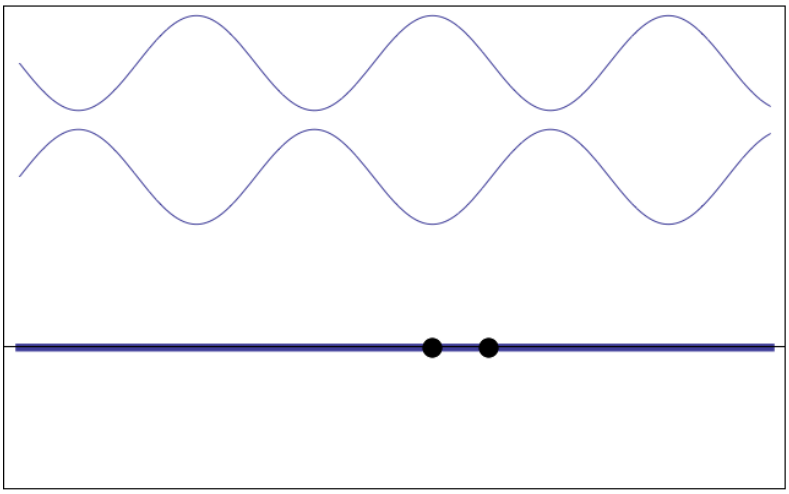
Welcome to VSWR!



YIKES 100% reflected power!

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Can we fix this?

- All we have to do is get back in phase
- Resistors can't do that – what else can we use?
- Inductors and capacitors shift phase in opposite directions

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It's Just Like a Slinky

- Capacitors and inductors both store energy
- As one charges, the other discharges
- Add it to your transmitter to get V and I timed right for your antenna

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Say hello to your “antenna tuner”

- Suppose we have a completely resistive transmitter
  (not actually possible)
- And an antenna impedance of 5+j3
- The phase angle results in power loss
- How do we make it go away?
- Add 5-j3 and we end up with just a resistor

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We already did that!

- (Return to the 90 degree example
- (do NOT sweat the units

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All the math is in the box

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But Hang on…

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What does your tuner actually tune?

- Everything – all the way to the edge of the universe
- Your feed line
- Every connector
- Bad solder joints
- Your antenna, including its counterpoise
- And even the mismatch between your antenna and space itself!

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Key points to remember

- All circuits are complete circuits – intended or not
- It takes two polarities to radiate – they will find a way, even if you don't
- RF is everywhere, planned or not (so plan)
- Everything conductive is a receive antenna
- All current flow is a transmitter
- Complex numbers are simple when you ignore the (unnecessary) math
- Matchmaking is a good thing and dead easy

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