Amateur Radio for Packet-Based Communication with Low Earth Orbit Satellites

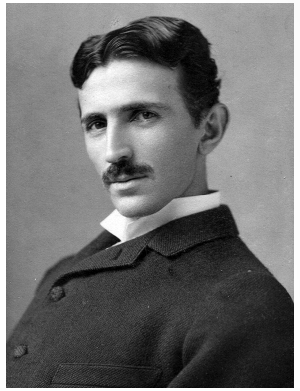
Samuel Harkness

Overview

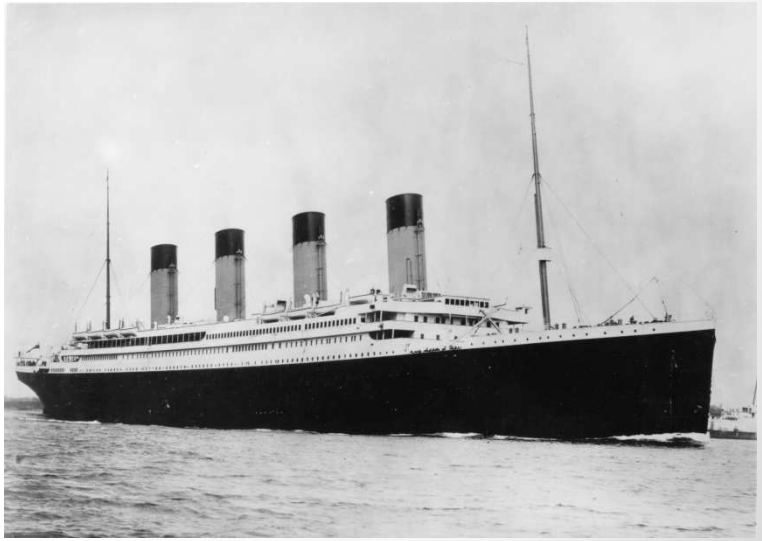
- Background
  - Amateur Radio
  - Packets on Amateur Radio
  - Amateur Radio on Satellites
- Satellite Radio System
  - AX.25
  - Radio System

Amateur Radio

- Hertz, Tesla, Marconi
- Columbia University Wireless Telegraph Club

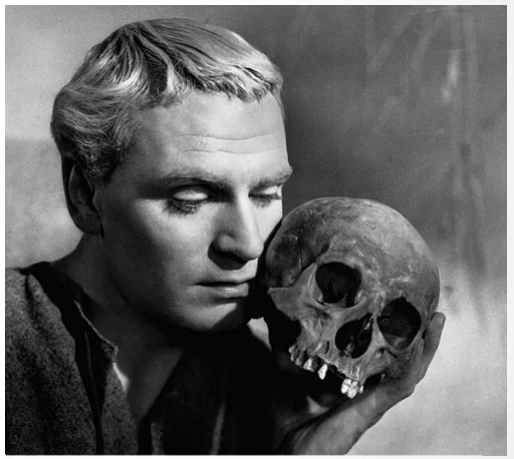



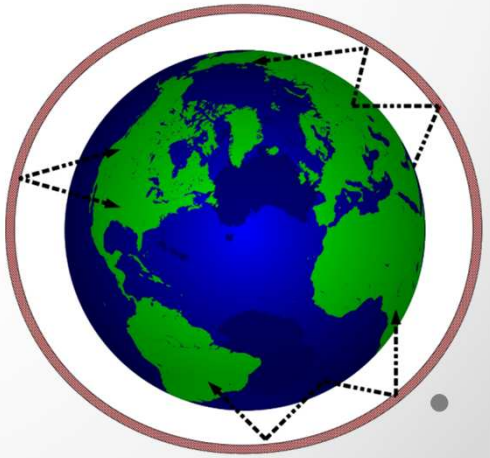

- Sinking of the RMS *Titanic*



Amateur Radio

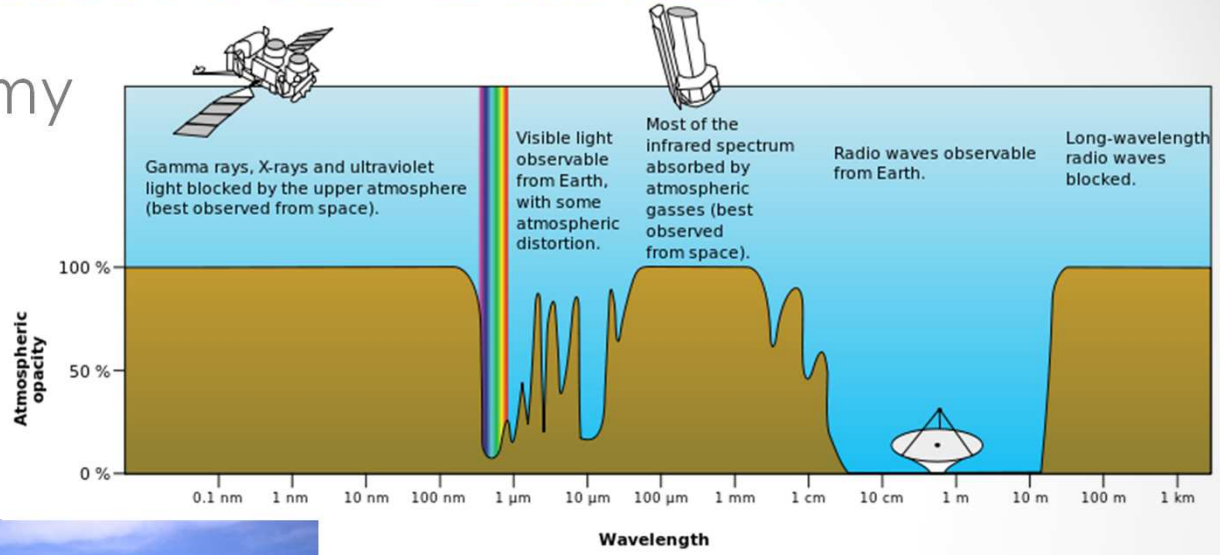
- Radio Act of 1912
  - Private Stations restricted to 200 – 10m (1500 kHz – 30 MHz)
- Shortwave Radio
  - Skywave Propagation
  - Higher data rate
  - Less Power
- International Communication





Amateur Radio

- Radio Astronomy
- Moon Bounce



US Amateur Radio Bands

Effective Date
March 5, 2012

Published by:
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www.arrl.org
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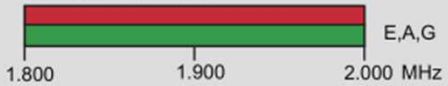
US AMATEUR POWER LIMITS

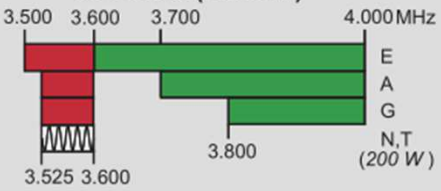
FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications. (b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.

160 Meters (1.8 MHz)

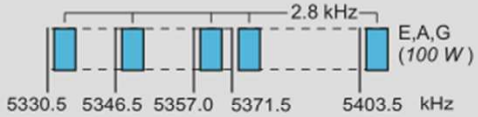
Avoid interference to radiolocation operations from 1.900 to 2.000 MHz



80 Meters (3.5 MHz)

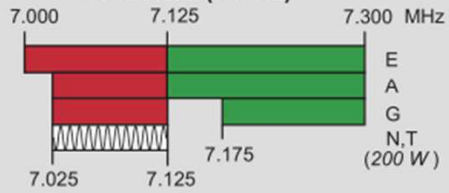


60 Meters (5.3 MHz)



General, Advanced, and Amateur Extra licensees may operate on these five channels on a secondary basis with a maximum effective radiated output of 100 W PEP. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III as defined by the FCC Report and Order of November 18, 2011. USB is limited to 2.8 kHz centered on 5332, 5348, 5358.5, 5373 and 5405 kHz. CW and digital emissions must be centered 1.5 kHz above the channel frequencies indicated above. Only one signal at a time is permitted on any channel.

40 Meters (7 MHz)

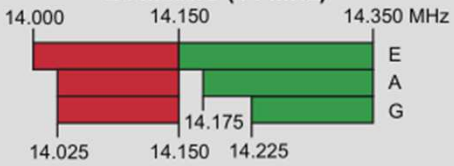


Phone and Image modes are permitted between 7.075 and 7.100 MHz for FCC licensed stations in ITU Regions 1 and 3 and by FCC licensed stations in ITU Region 2 West of 130 degrees West longitude or South of 20 degrees North latitude. See Sections 97.305(c) and 97.307(f)(11).
Novice and Technician licensees outside ITU Region 2 may use CW only between 7.025 and 7.075 MHz and between 7.100 and 7.125 MHz. 7.200 to 7.300 MHz is not available outside ITU Region 2. See Section 97.301(e). These exemptions do not apply to stations in the continental US.

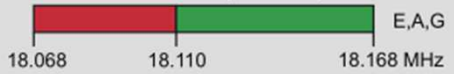
30 Meters (10.1 MHz)

Avoid interference to fixed services outside the US.

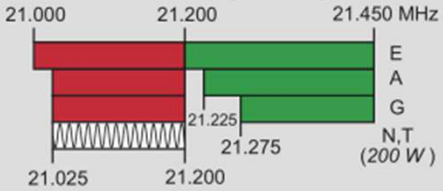
20 Meters (14 MHz)



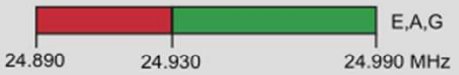
17 Meters (18 MHz)



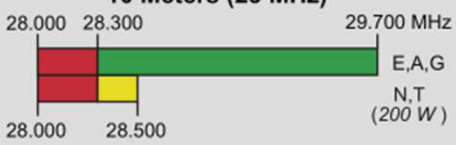
15 Meters (21 MHz)



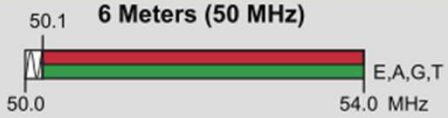
12 Meters (24 MHz)



10 Meters (28 MHz)

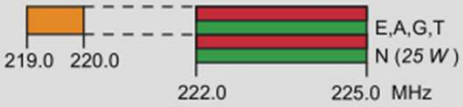


6 Meters (50 MHz)



2 Meters (144 MHz)

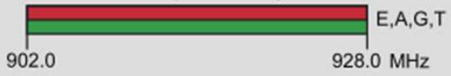
1.25 Meters (222 MHz)



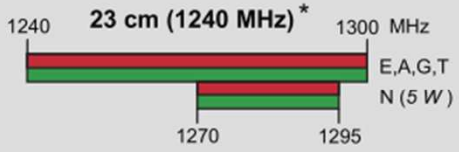
*Geographical and power restrictions may apply to all bands above 420 MHz. See *The ARRL Operating Manual* for information about your area.

70 cm (420 MHz)*

33 cm (902 MHz)*



23 cm (1240 MHz)*



All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	10.0-10.5 GHz *	122.25-123.0 GHz
2390-2450 MHz	24.0-24.25 GHz	134-141 GHz
3300-3500 MHz	47.0-47.2 GHz	241-250 GHz
5650-5925 MHz	76.0-81.0 GHz	All above 275 GHz

* No pulse emissions

KEY

Note:
CW operation is permitted throughout all amateur bands.

MCW is authorized above 50.1 MHz, except for 144.0-144.1 and 219-220 MHz.

Test transmissions are authorized above 51 MHz, except for 219-220 MHz

- = RTTY and data
- = phone and image
- = CW *only*
- = SSB phone
- = USB phone, CW, RTTY, and data
- = Fixed digital message forwarding systems *only*

E = Amateur Extra
A = Advanced
G = General
T = Technician
N = Novice

See *ARRLWeb at www.arrl.org* for detailed band plans.

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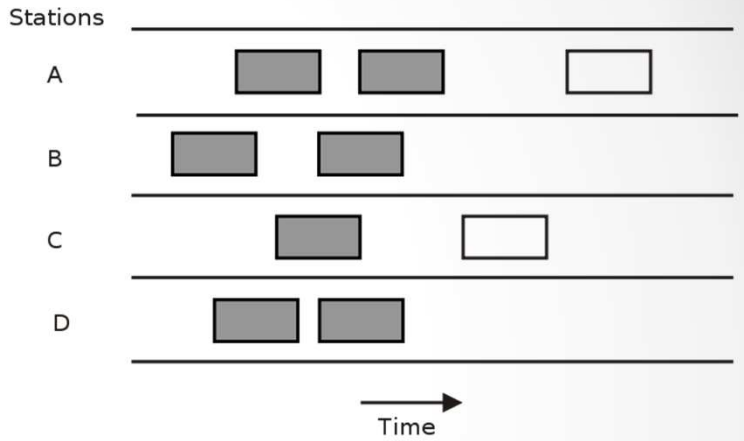
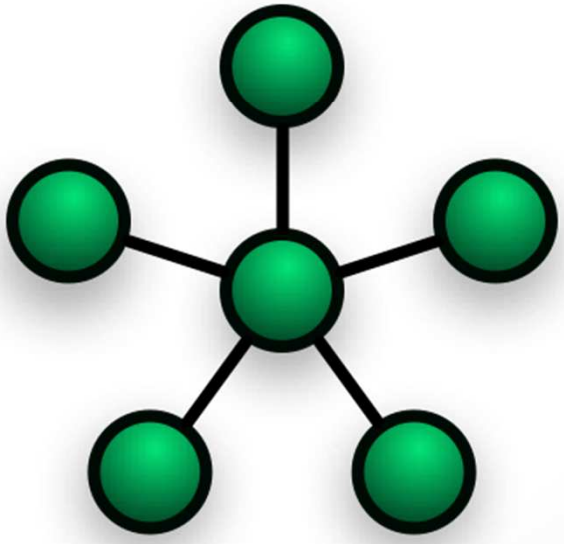
 rev. 4/12/2012

Packets on Amateur Radio

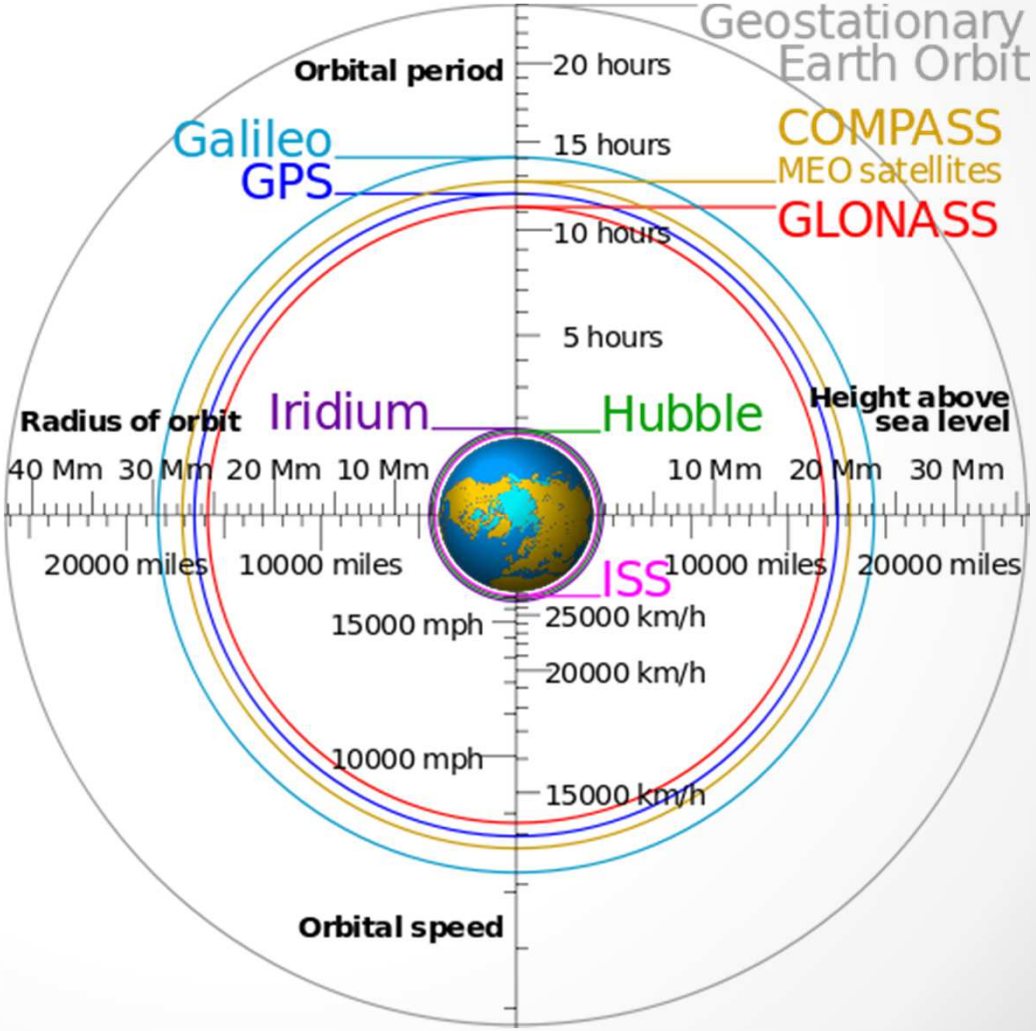
- ALOHAnet
  - Hub Topology
  - Full Duplex (Two Frequencies)
- PRnet
  - Wireless offshoot of ARPAnet
- AMPRnet
  - Supports TCP/IP





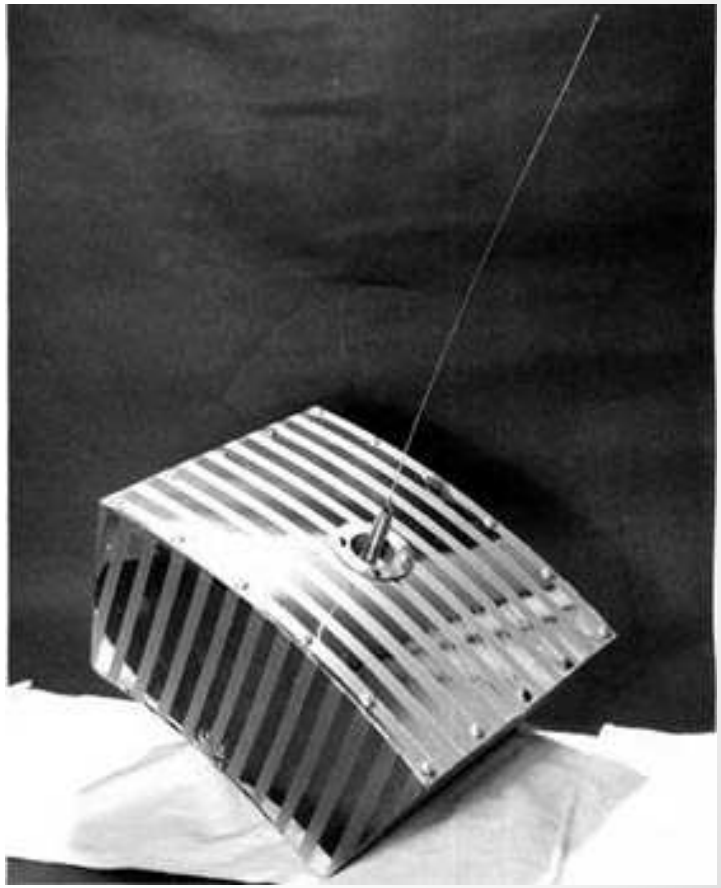
Amateur Radio on Satellites

- Low Earth Orbit
  - 160 km – 2,000 km
  - 88 min – 127 min



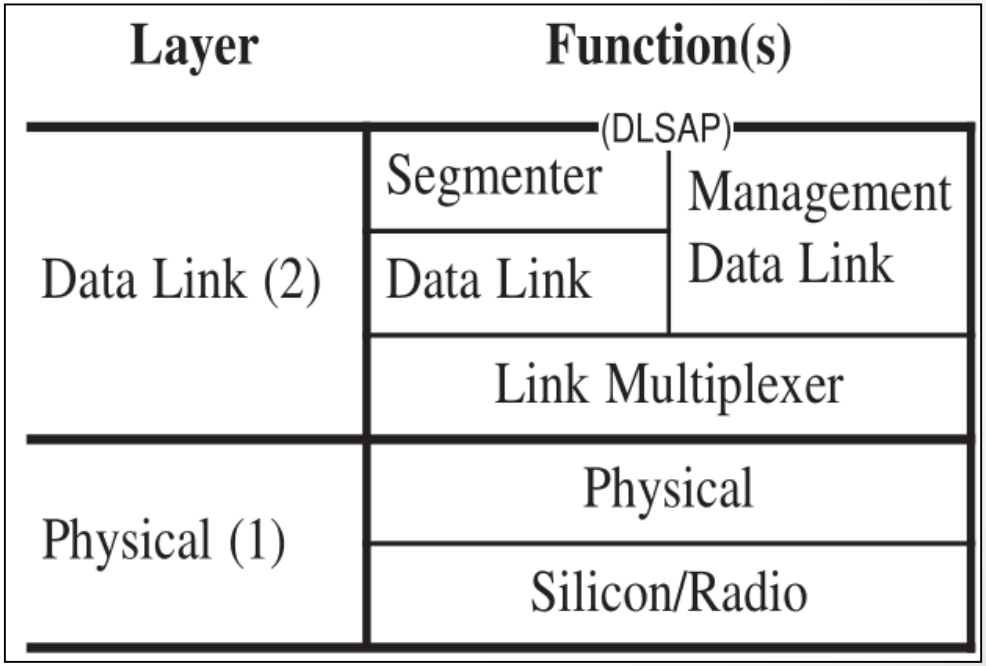
Amateur Radio on Satellites

- OSCAR
  - 12 Dec 1961
  - 4 years after Sputnik 1
  - Replaced one of the balance weights
  - First satellite as a secondary payload
  - 22 days, 570 hams, 28 countries
- Over 70 satellites



AX.25

- Derived from X.25
- Link Layer Protocol (Data Link Layer)
- ISO 3309, 4335, 7809



AX.25

- 3 General Frame Types
  - Information (I)
  - Supervisory (S)
  - Unnumbered (U)

Flag	Address	Control	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	N*8 Bits	16 Bits	01111110

Figure 3.1a. U and S frame construction.

Flag	Address	Control	PID	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	8 Bits	N*8 Bits	16 Bits	01111110

Figure 3.1b. Information frame construction.

- Subsequent Frames can share Start/Stop Flag
- Address contains Source & Destination
-

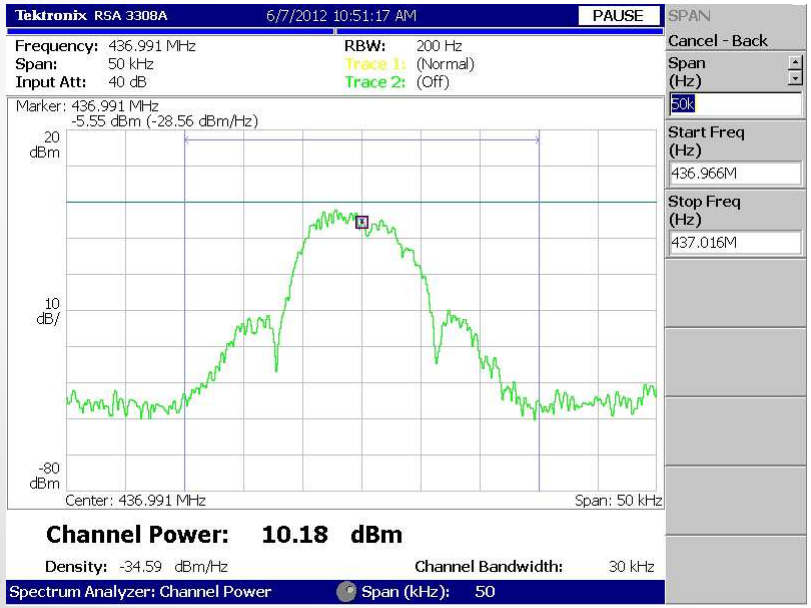
AX.25

- Control determines type of frame
- PID identifies the OSI Layer 3 protocol
  - AX.25
  - IP
- Protects the 8-bit Flag using bit-stuffing
- Frame-Check Sequence is Forward Error Correction

HEX	MSB LSB	Translation
**	yy01yyyy	AX.25 layer 3 implemented.
**	yy10yyyy	AX.25 layer 3 implemented.
0x01	00000001	ISO 8208/CCITT X.25 PLP
0x06	00000110	Compressed TCP/IP packet. Van Jacobson (RFC 1144)
0x07	00000111	Uncompressed TCP/IP packet. Van Jacobson (RFC 1144)
0x08	00001000	Segmentation fragment
0xC3	11000011	TEXNET datagram protocol
0xC4	11000100	Link Quality Protocol
0xCA	11001010	Appletalk
0xCB	11001011	Appletalk ARP
0xCC	11001100	ARPA Internet Protocol
0xCD	11001101	ARPA Address resolution
0xCE	11001110	FlexNet
0xCF	11001111	NET/ROM
0xF0	11110000	No layer 3 protocol implemented.
0xFF	11111111	Escape character. Next octet contains more Level 3 protocol information.
Escape character. Next octet contains more Level 3 protocol information.	00001000	

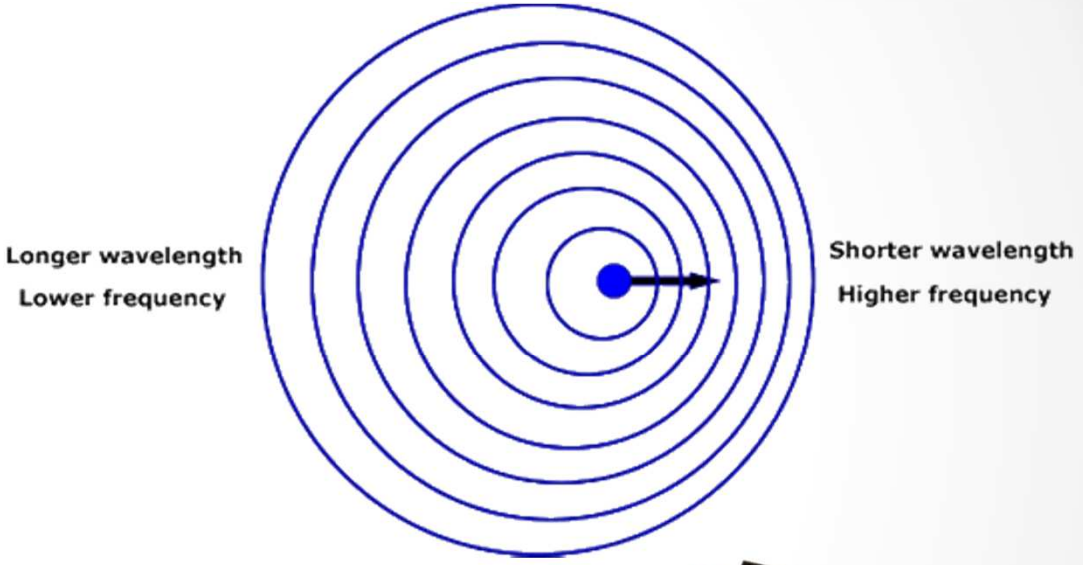
Radio

- 1.1W RF power
- Downlink 437.000 MHz
- Uplink 145.800 MHz
- Frequencies change slightly mission-to-mission
  - Request allocation through IARU and FCC



Radio

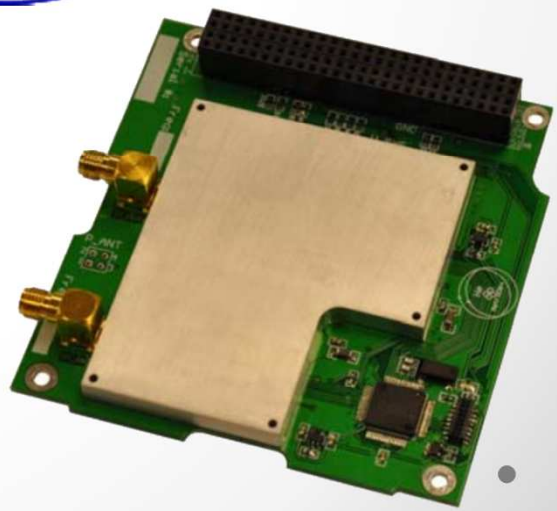
- Doppler Effect



Change in Frequency
$$\Delta f = f \times \frac{v}{c}$$

Downlink Correction
$$f_d = f(1 + \frac{v}{c})$$

Uplink Correction
$$f_u = f(1 - \frac{v}{c})$$



Radio

- Beacon Mode
  - 214 byte chunks @ 9600 bps
  - Period is dependent on power constraints
- Downlink Mode
  - 231 byte chunks @ 19200 bps
  - Can only operate Line of Sight
  - 20 degrees above the horizon, 5 min

Summary

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- Satellite Radio System
  - AX.25
  - Radio System

Questions?

References

[1] ARRL, ed. Frequency Bands Chart. 2012. url: http://www.arrl.org/graphical-frequency-allocations.

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