Introduction to Amateur Radio Satellites

Douglas Quagliana, KA2UPW

Pacificon – October 2008

Introduction

- AMSAT
- What can you do / expect?
- What do you really need?
- Satellite antennas you can build
- Which satellites? When?
- Tracking basics

AMSAT

- Radio Amateur Satellite Corporation
- Worldwide – AMSAT-NA, AMSAT-UK, AMSAT-DL, AMSAT India
- All volunteers – only one employee (Martha)
- Design, build, and launch amateur radio satellites
- Founded in 1969 as an educational organization
- First amateur radio satellite, OSCAR-1, launched in 1961 by Project Oscar

What's it all about? What are amateurs doing?

- Experimenting with new modes of communications – FEC, SSTV, APRS
- Advanced digital signal processing
- Analyzing spacecraft telemetry and orbits
- Designing and building spacecraft
- Talking to other amateurs around the world and on the International Space Station
- Having fun! Why satellites? It's a lot like "Fishing"

What can you expect?

- Satellite passes are extremely predictable (unlike HF / shortwave propagation)
- Grid square chasing / DX chasing
- Satellites operate in one or more modes – not everything on the satellite is turned on all of the time
- Voice – single sideband (SSB) and FM
- Data – APRS and Instant Messaging like communications, telemetry, “flying BBS”

What can you expect?

- Some aspects are fast and dynamic – new and different things are always happening.
- You might have to check your email and/or the website(s) to keep up and to find out what's happening this week.
- *This week:* Richard Garriot, W5KWQ, is a visitor on the International Space Station and is sending down slow scan TV pictures on two meters. Next week he returns to Earth.

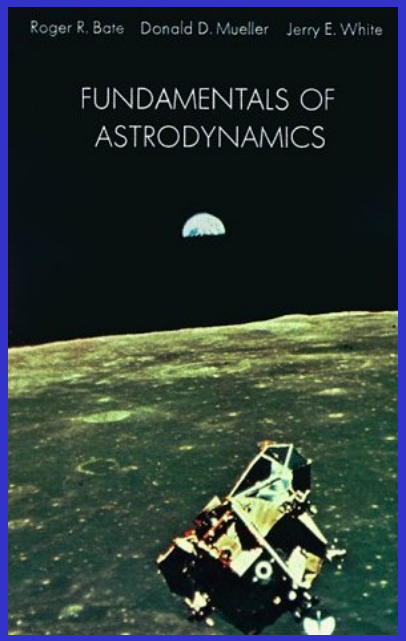
This week

Photo by Fred Pace, 9H1FF

Photo by
Michael Seguin, N1JEZ

Every week

- Looking to learn something? Some aspects don't change much. Orbital mechanics, much like Ohm's Law, hasn't changed much recently.



Fundamentals of Astrodynamics

Methods of Orbit Determination

WARNING: May cause headaches.

What kind of equipment do you need?

"The MYTH" is that you need:

- multiple large antennas
- great big huge satellite dishes
- hundreds of watts of power
- thousands of dollars worth of radios
- a huge investment in your time to learn the basics before you can do anything

What kind of equipment do you need?

What kind of equipment do you need?

What kind of equipment do you REALLY need?

"The REALITY" : you can *get started* with just a two meter FM HT, a 70cm HT (a hand held scanner), and some home made antennas. Got an FT817?

- Which satellite(s) do you want to use? What do you want to do? Some satellites use FM. Others use SSB/CW. What equipment do you already have?

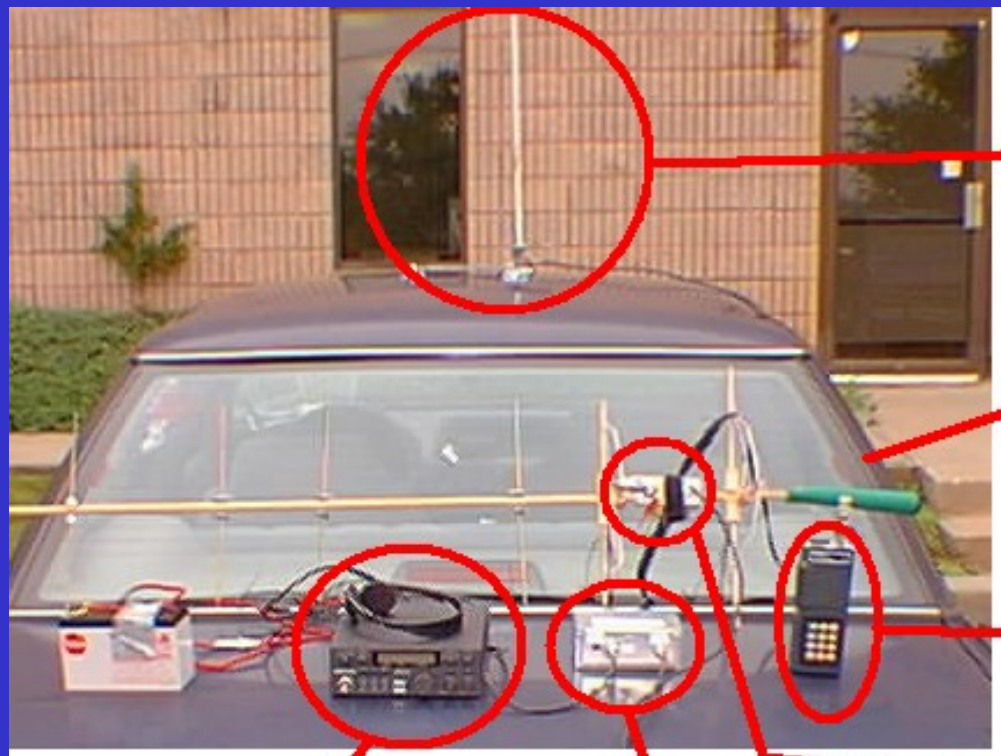
Arrow Antenna and FT-817

Photo W5UI Keith Pugh at Dayton 2008

Equipment for beginners

Photo by Douglas Quagliana, KA2UPW

Equipment for beginners



5/8-wavelength 146 MHz (2M) antenna with homemade magnetic mount

Homemade 435 MHz Quagi (~$10) antenna

1980's vintage 146 MHz (2M) HT (1.5 watts)

D.E.M. 435 MHz preamplifier

Hamtronics 435 MHz downconverter

HR2600 28MHz (10M) for receive

Photo by Douglas Quagliana, KA2UPW

Equipment for beginners - Closeup

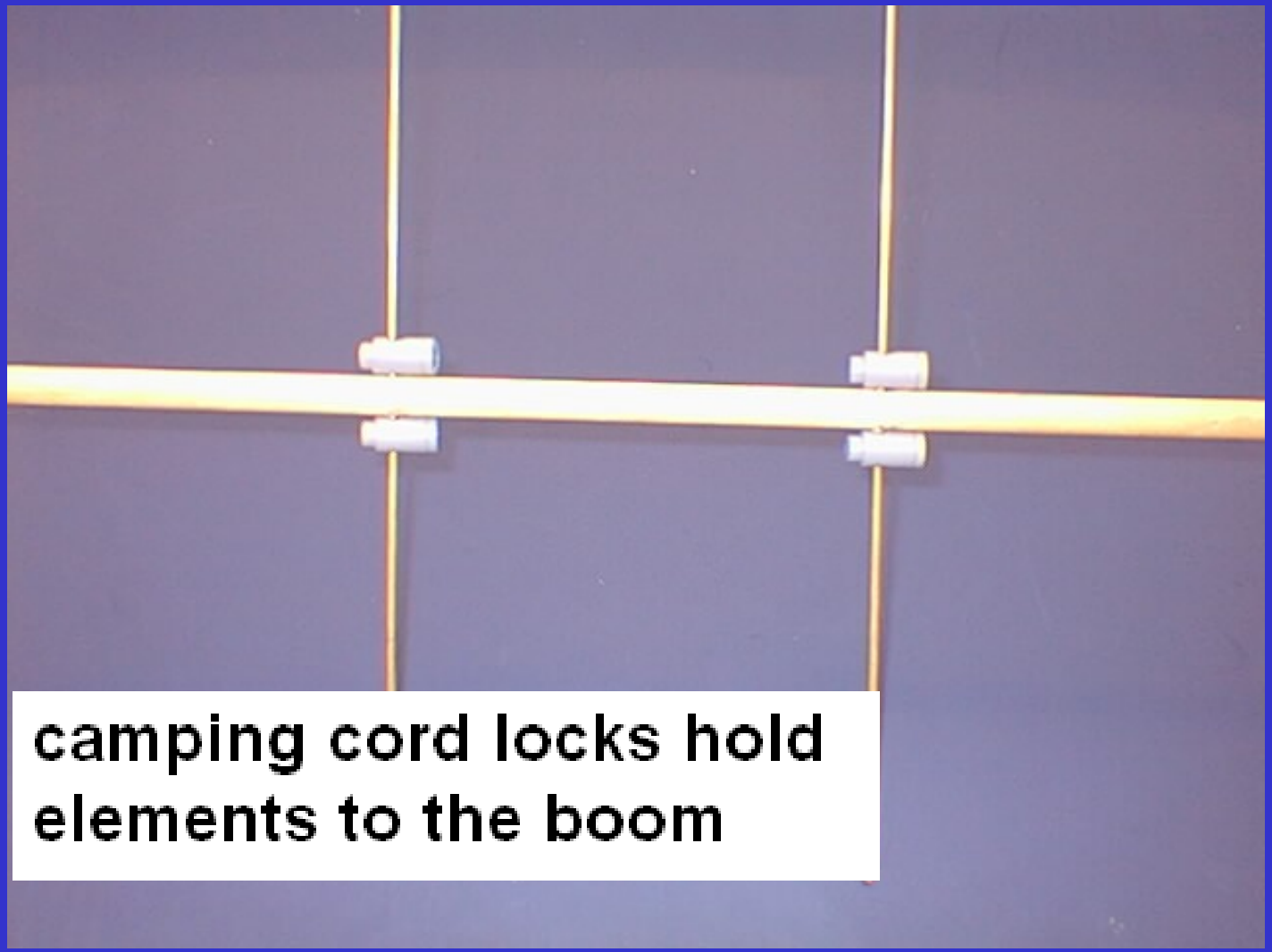


Photo by Douglas Quagliana, KA2UPW

Equipment for beginners who build

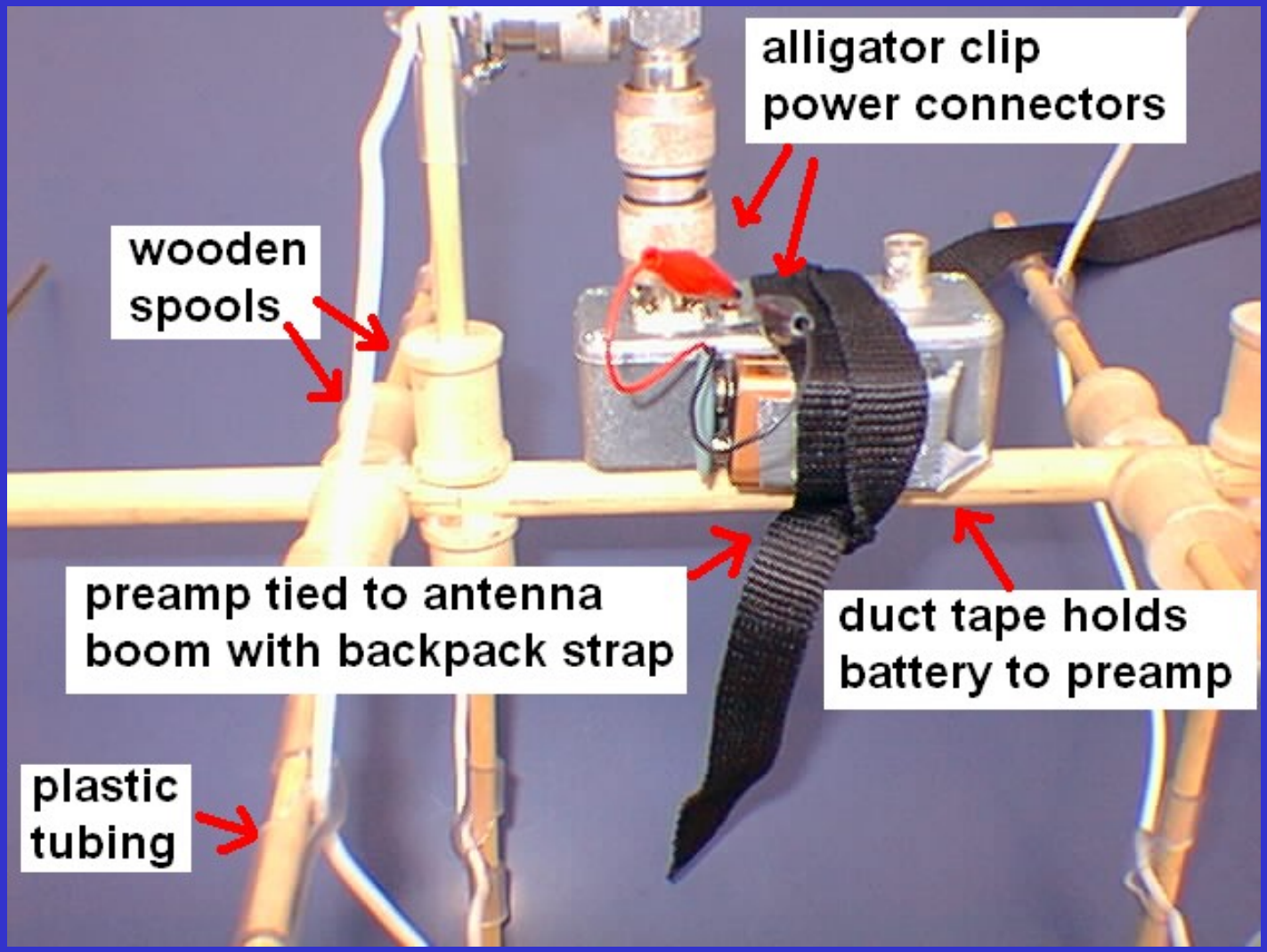


Photo by Douglas Quagliana, KA2UPW

Equipment for beginners who buy

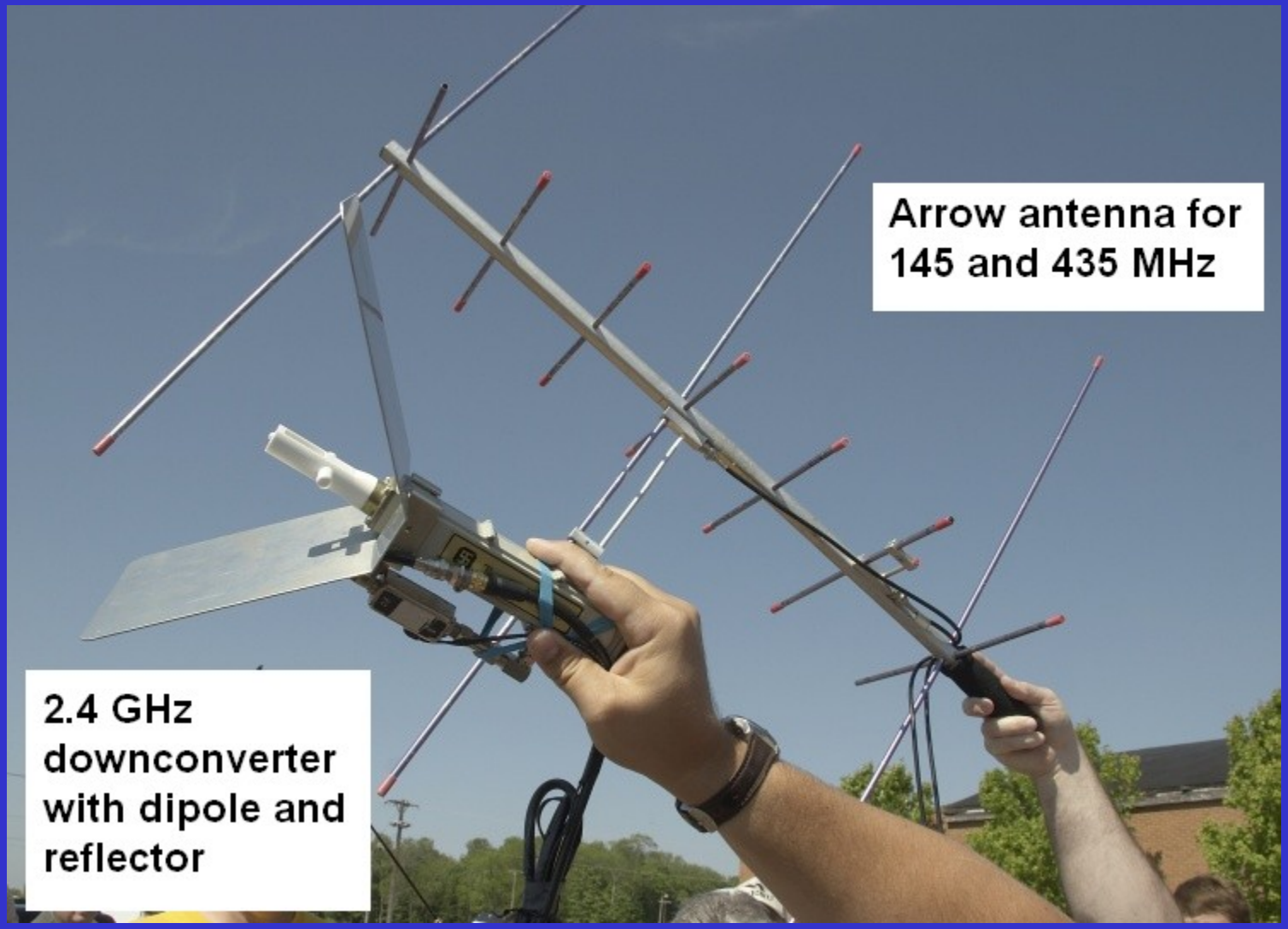


Photo by Tom Clark, W3IWI

Building Antennas Satellites

- Why does an antenna work well?
  - Because it was expensive?
  - Because it has:
    - Metal pieces
    - Right Size
    - Correct Shape
    - Proper Position/Distance from other pieces of metal
- Hey, want to buy a bridge? Can you?
- “Engineering is the art of making what you want from things you can get.” -Jerry Avins

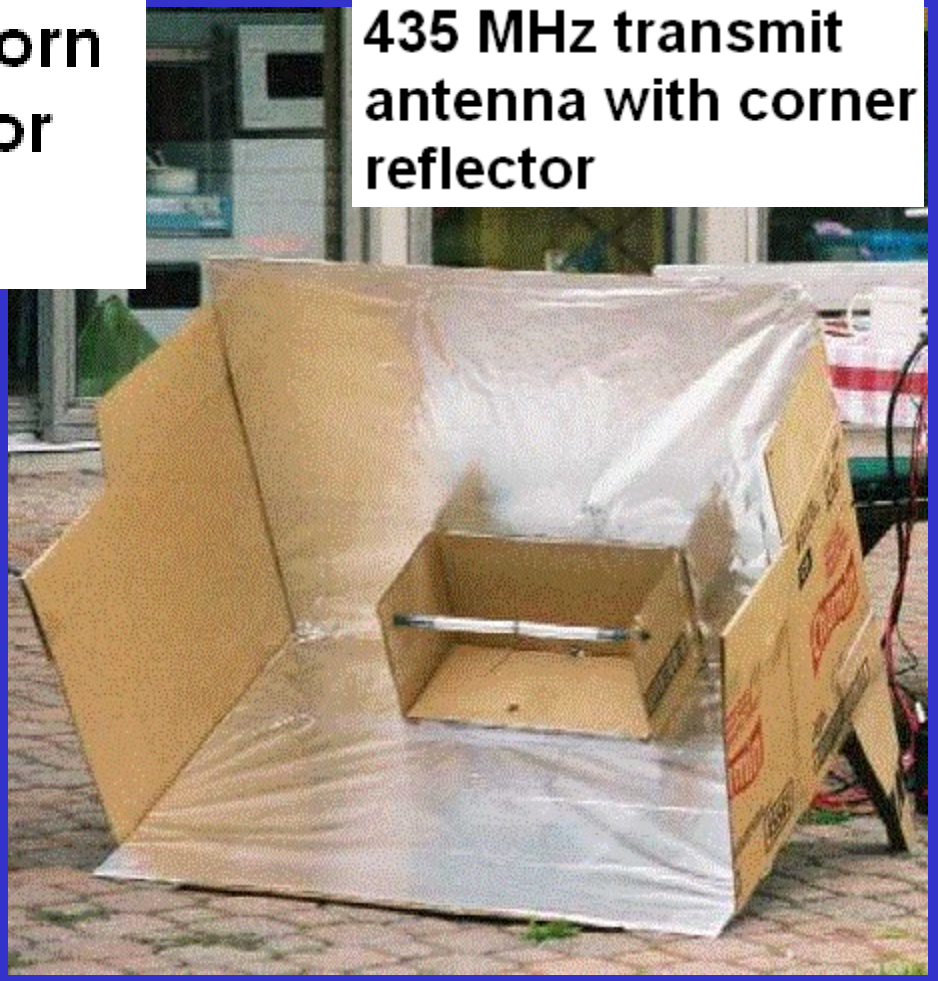
Building Antennas Satellites

- Regular magnetic mount vertical (145 MHz) - homebrew from deck parts at hardware store
- Kent Britain's "Cheap Yagis" (145 MHz, 435 MHz and higher) www.wa5vjb.com or google "cheap yagi"
- Arrow or homebrew arrow (145 and 435 MHz)
- Cardboard and foil corner reflector (435 MHz)
- Simple 2.4 GHz antennas: umbrella dish, homebrew helix, patch antenna from a mint tin, cardboard and aluminum foil horn antenna

Cardboard & Aluminum Foil Antennas

2.4 GHz horn antenna for receive

Photo by Douglas Quagliana, KA2UPW



435 MHz transmit antenna with corner reflector

Photo by Anthony Monteiro, AA2TX

Antennas - 2.4 GHz is *not* scary

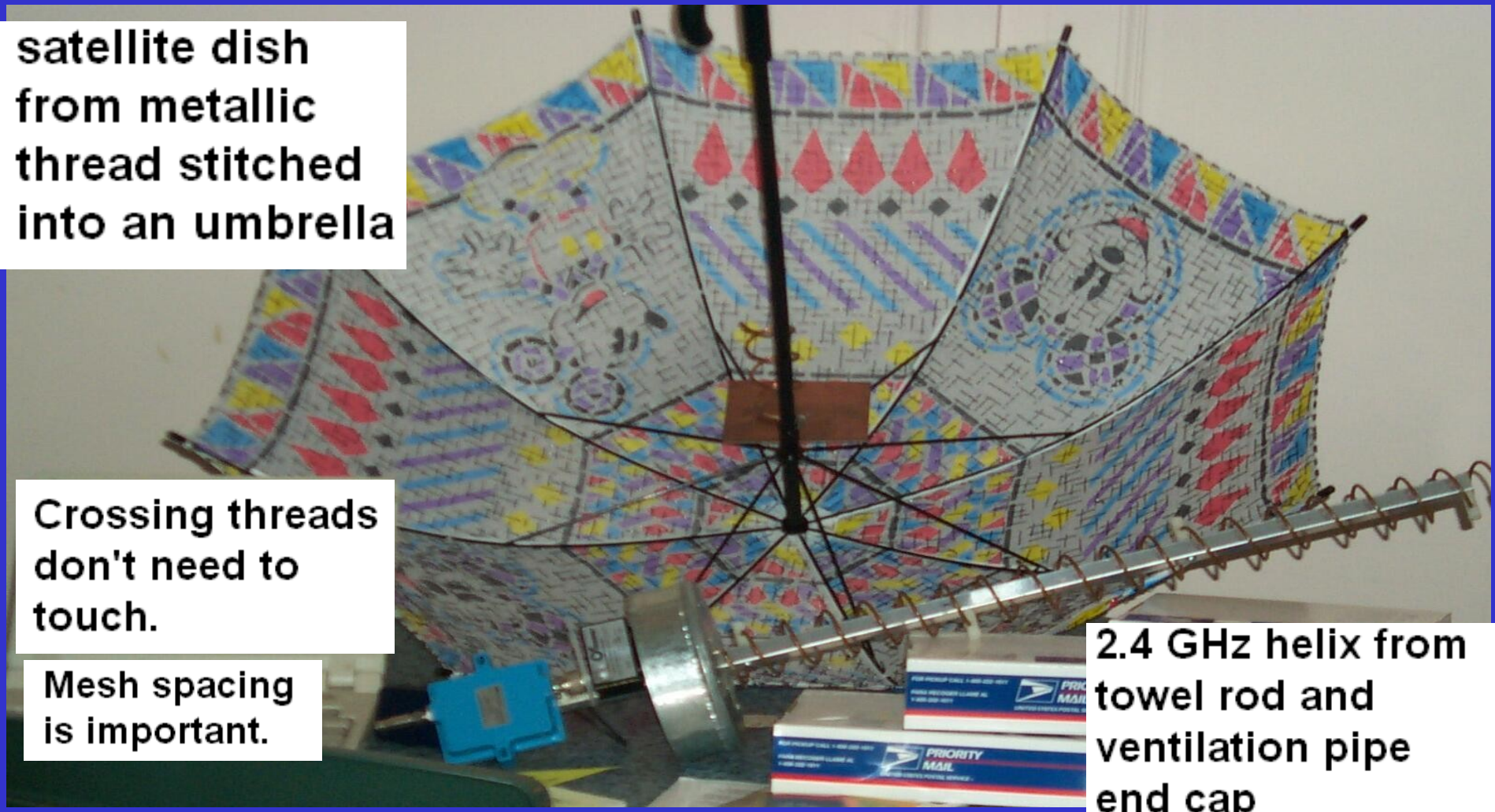
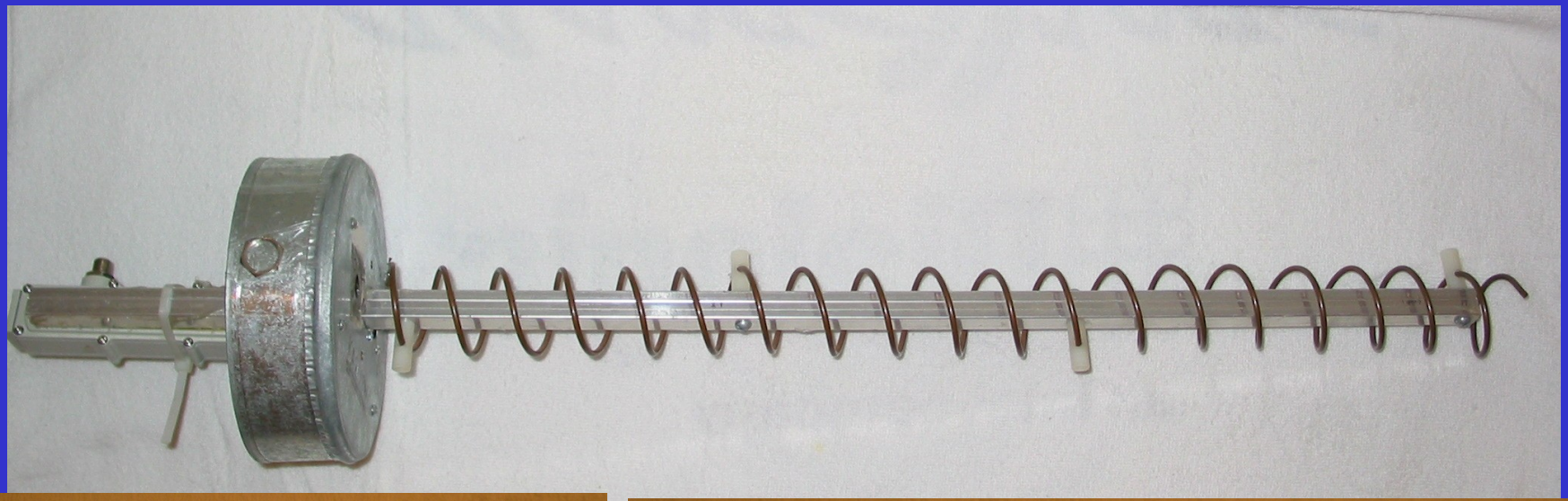
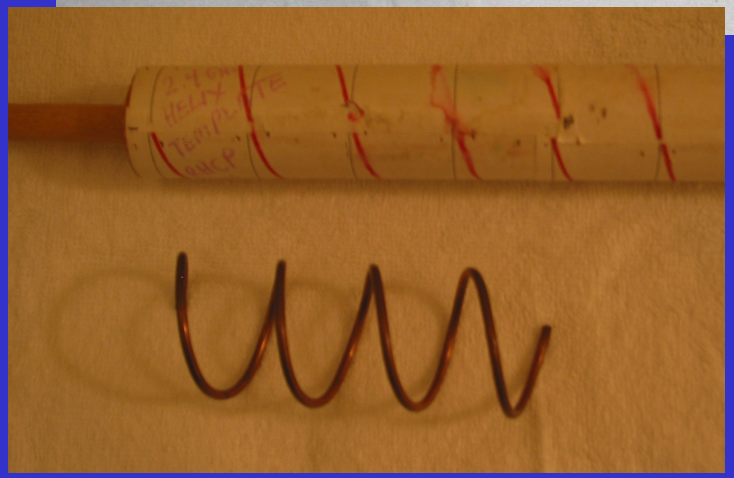


Photo courtesy NJQRP

Antennas - 2.4 GHz is *not* scary





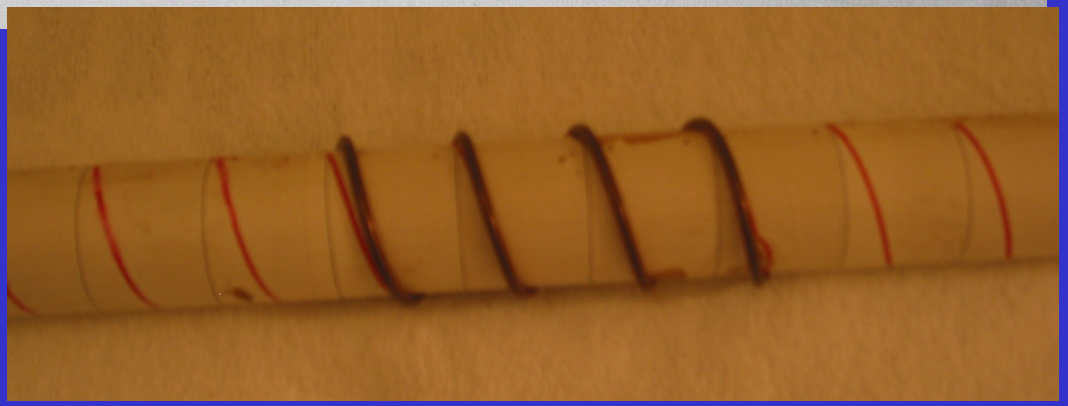
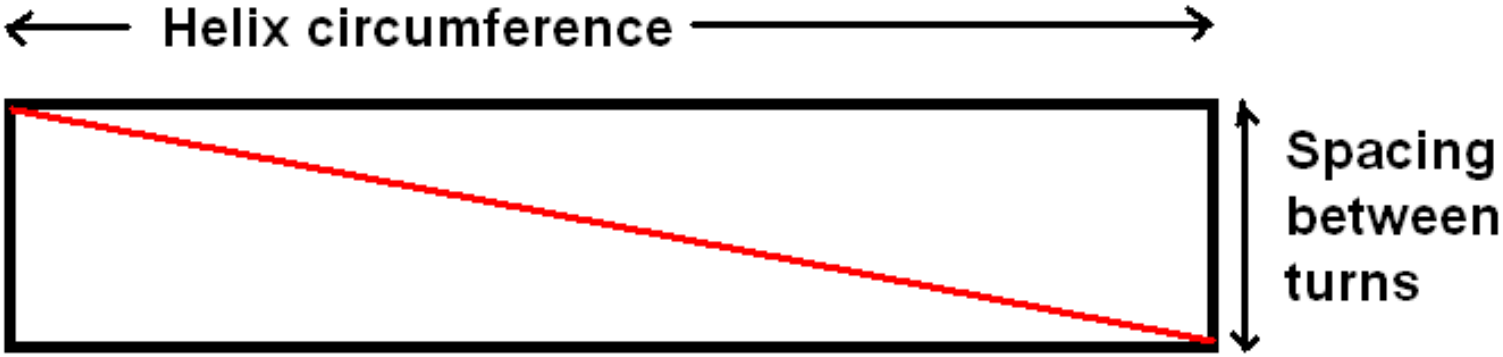


Photo by Douglas Quagliana, KA2UPW

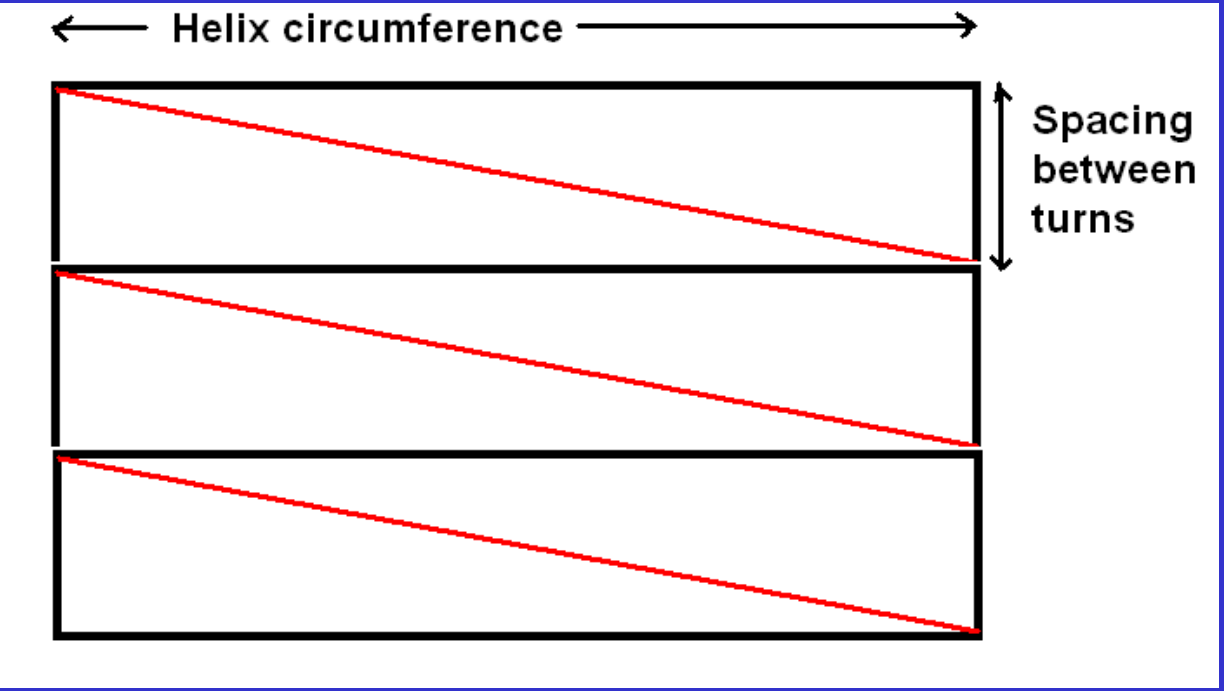
How to build the perfect helix



Make a template on paper that uses the dimensions of the helix to define a "box" and then draw a diagonal through the box.

Photo by Douglas Quagliana, KA2UPW

How to build the perfect helix



Make as many boxes as you have turns.
Glue the template to the wooden dowel.

Photo by Douglas Quagliana, KA2UPW

Adhesive foil tape and 24-inch snow sled/saucer parabolic (almost) dish

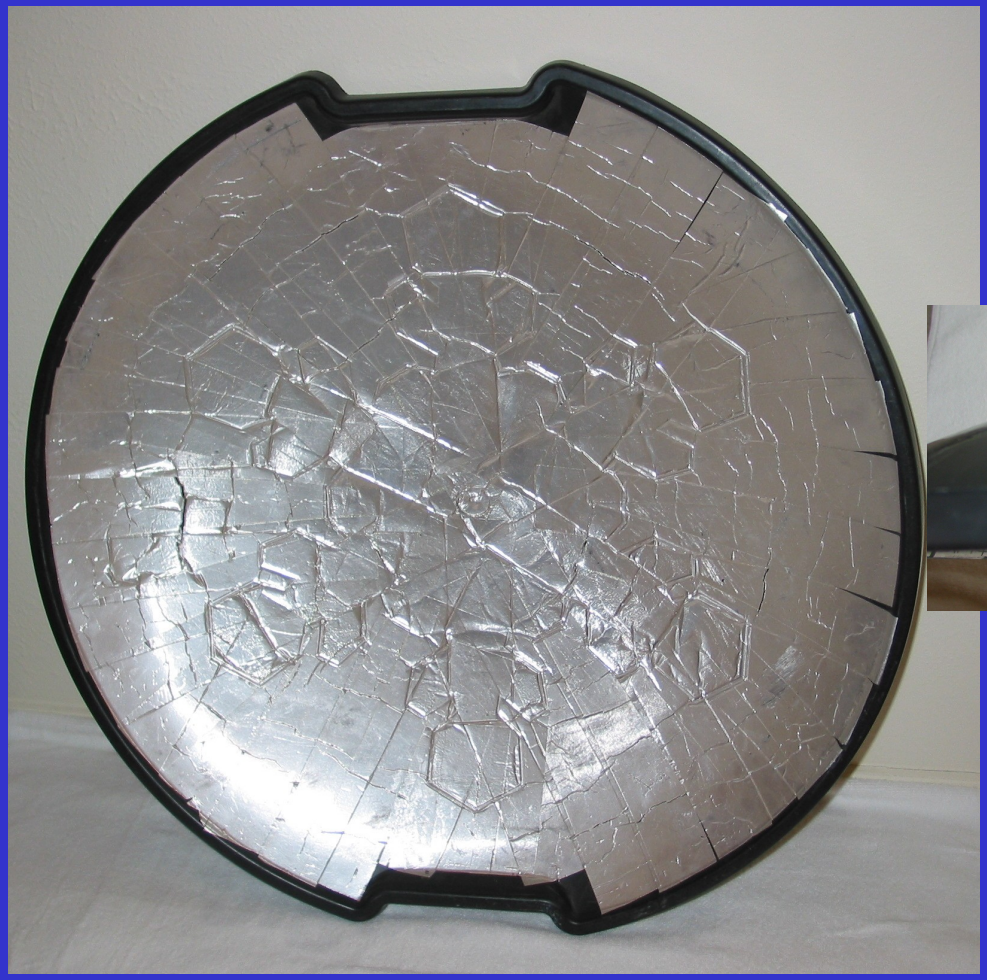


Photo by Douglas Quagliana, KA2UPW

It's almost parabolic

It's close enough to parabolic that we still get plenty of gain.

2.4 GHz patch antenna -K3TZ design

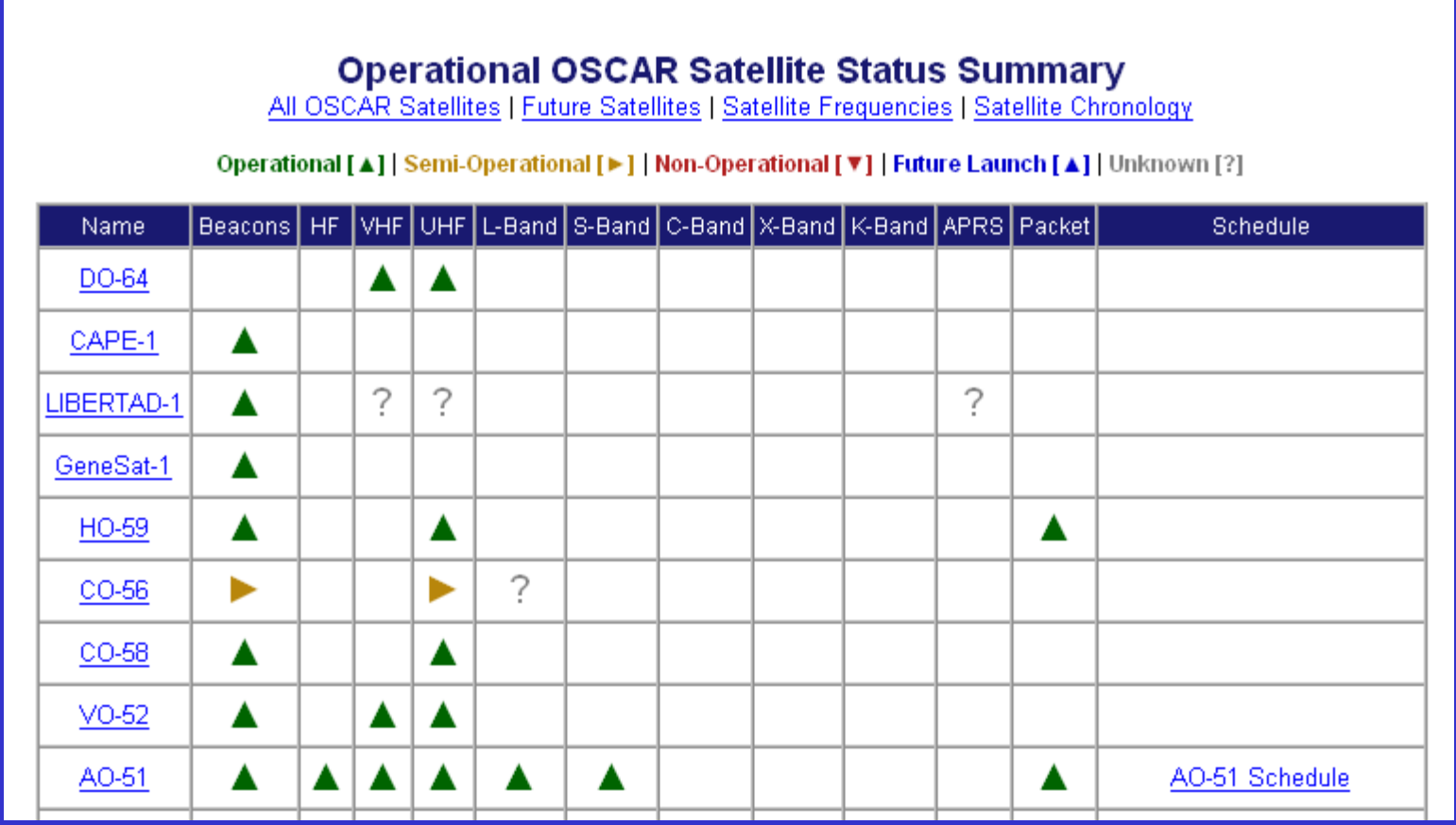
7.5 dBi gain at 2.4 GHz, just measure, cut, and solder. There's only ONE solder joint. And you *know* you already have a bunch of these mint tins.

Photos by Douglas Quagliana, KA2UPW

Which satellites are active “now?”

- Not all satellites are active all the time
- Satellite have “modes” – selected receivers and transmitters are turned on and off according to a published schedule. What's on *TODAY*? 2.4 GHz?
- See AMSAT News bulletins (ANS), amsat-bb mailing list, AMSAT website
- Echo (AO-51), Hamsat (VO-52), AO-7 (sunlit only), AO-27, ISS, SO-50, PCSAT... and more!

Which satellites are active “now”?



Operational OSCAR Satellite Status Summary

All OSCAR Satellites | Future Satellites | Satellite Frequencies | Satellite Chronology

Operational [▲] | Semi-Operational [►] | Non-Operational [▼] | Future Launch [▲] | Unknown [?]

Name	Beacons	HF	VHF	UHF	L-Band	S-Band	C-Band	X-Band	K-Band	APRS	Packet	Schedule
DO-64			▲	▲								
CAPE-1	▲											
LIBERTAD-1	▲		?	?						?		
GeneSat-1	▲											
HO-59	▲			▲							▲	
CO-56	►			►	?							
CO-58	▲			▲								
VO-52	▲		▲	▲								
AO-51	▲	▲	▲	▲	▲	▲					▲	AO-51 Schedule

Table from http://www.amsat.org/amsat-new/satellites/status.php

Schedule for AO-51 Echo

AO-51 Monthly Schedule

For a complete description please see Control Team News (text format)

Schedule for June 2008

All dates begin at 0000 UTC, Sundays shown in gold

	Channel A		Beacon	Channel B	
	Uplink	Downlink		Uplink	Downlink
1	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
2	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
3	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
4	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
5	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
6	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
7	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
8	145.920 FM	435.300 FM	435.150 FM	1268.700 PBP 9k6	435.150 PBP 9k6
9	145.880 FM	2401.200 FM	Off	Off	Off
10	145.880 FM	2401.200 FM	Off	Off	Off
11	145.880 FM	2401.200 FM	Off	Off	Off
12	145.880 FM	2401.200 FM	Off	Off	Off
13	145.880 FM	2401.200 FM	Off	Off	Off

Schedule from http://www.amsat.org/amsat-new/echo/ControlTeam.php

When is the satellite available for you at your location?

- Amateur satellites are not geostationary (yet)
- Satellites in earth orbit appear to move -- rise (AOS) and set (LOS) at predictable times.
- These times are *different* every day.
- Azimuth (N-S-E-W) and elevation change
- Satellite “footprint” determines who is in range of the satellite which determines who can use the satellite to communicate
- Satellite “modes” determine what receivers and transmitters are turned on today or on this satellite pass

Tracking Satellites

- Originally tracked using simple rotating paper “computers”
- Tracking computer programs will calculate rise and set times, maximum elevation (the angle above the horizon) and minute to minute pointing directions in azimuth (N-S-E-W)
- Numerous tracking programs exist for Macs and PCs running Windows, Linux

Tracking Satellites

- *Any* computer is fast enough to track and predict satellites (HP-48, C64, XT, ...Pentium)
- Enter in your latitude, longitude
- Enter orbital elements (Keplerian elements)
- Graphical display or tabular text output
- You need to keep the orbital elements current (less than two weeks old)
- Your computer's clock needs to be accurate

Tracking Satellite

- Or, use www.heavens-above.com and select your location and then click on “Radio amateur satellites”
- Or, get predictions online at

http://www.amsat.org/amsat-new/tools/predict/

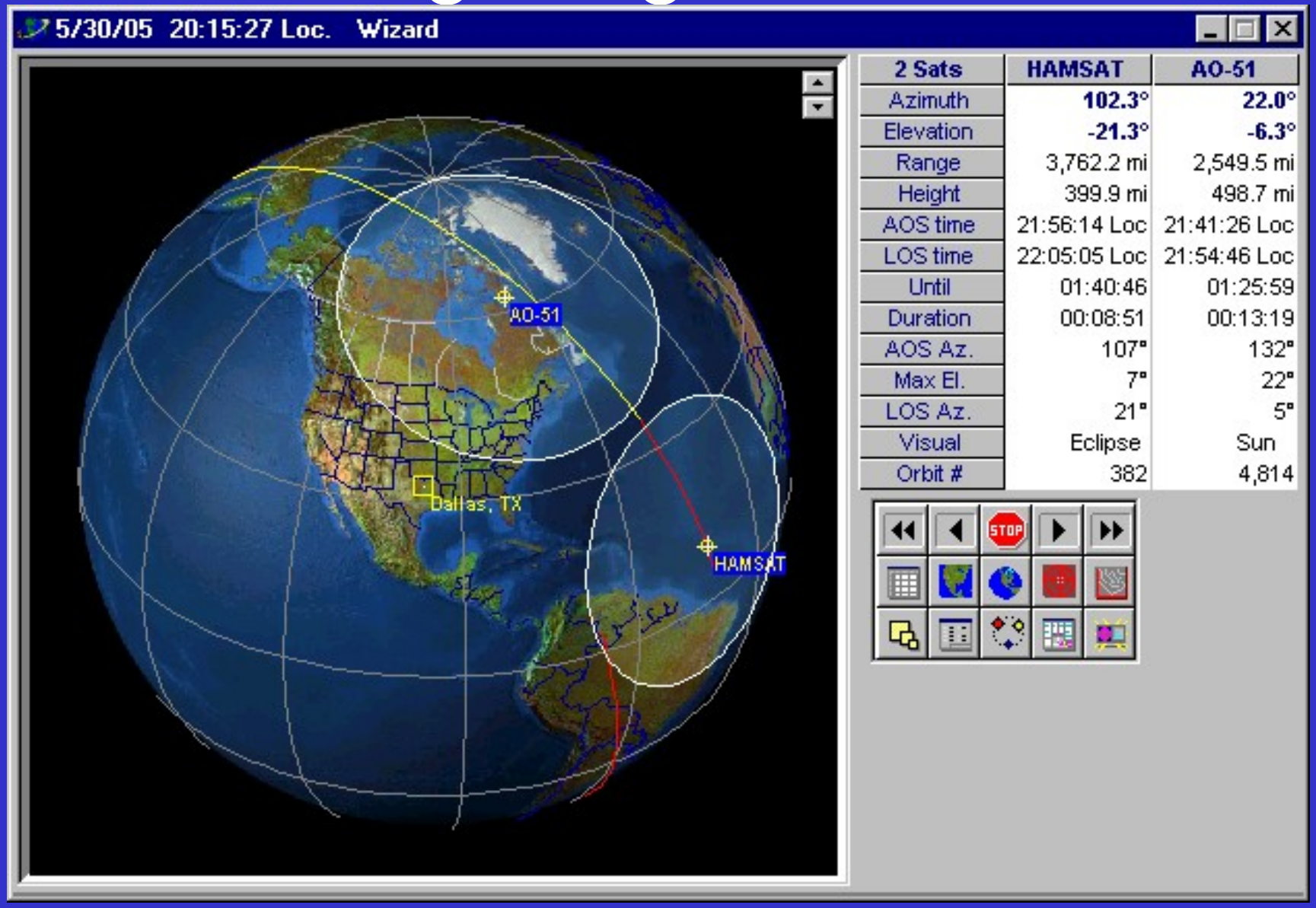
- AMSAT Software Archive / Tracking

http://www.amsat.org/amsat- new/tools/softwareArchive.php

http://www.amsat.org/amsat-new/tools/software.php

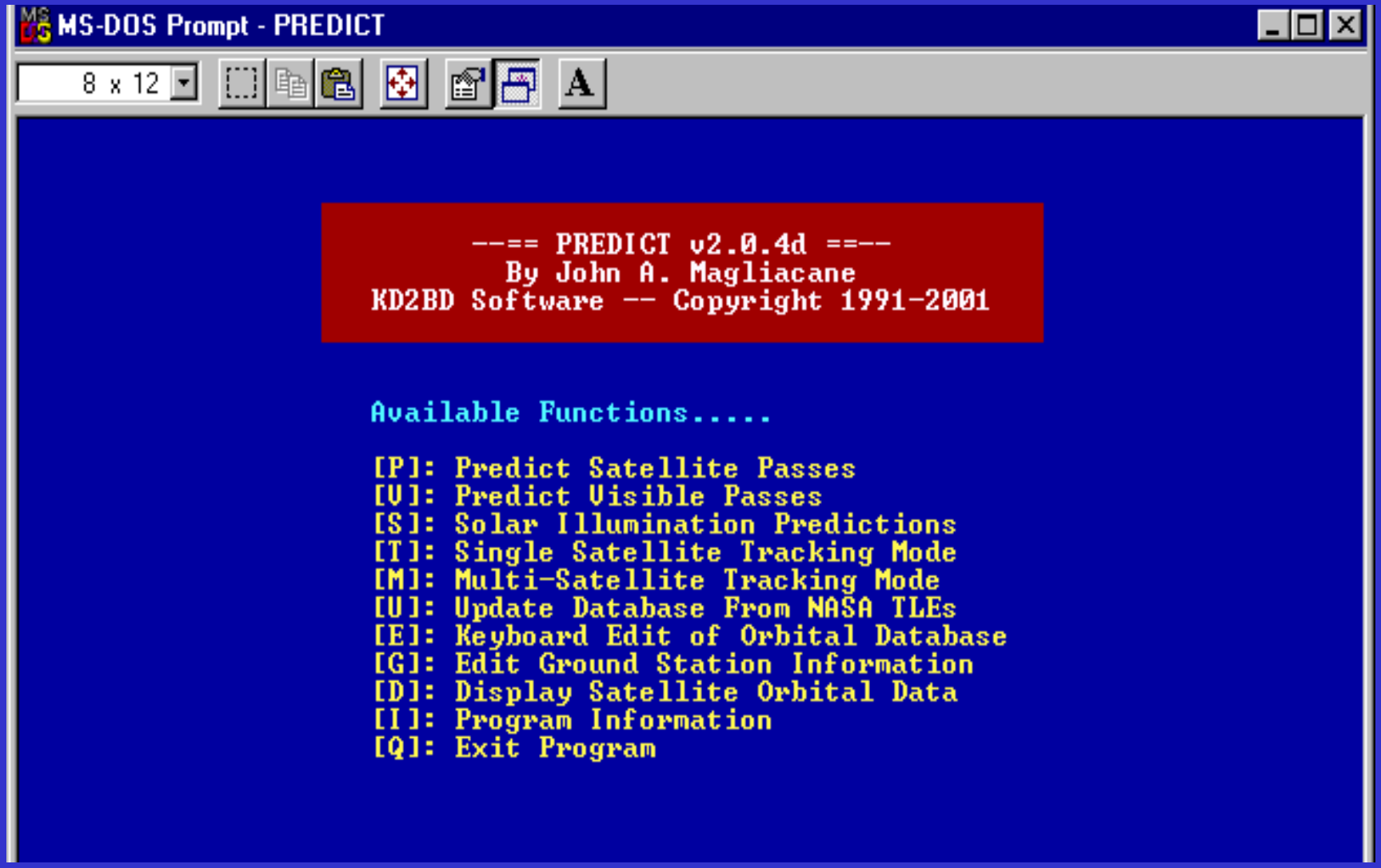
Tracking Programs - Nova

Tracking Programs - Nova



2 Sats	HAMSAT	AO-51
Azimuth	102.3°	22.0°
Elevation	-21.3°	-6.3°
Range	3,762.2 mi	2,549.5 mi
Height	399.9 mi	498.7 mi
AOS time	21:56:14 Loc	21:41:26 Loc
LOS time	22:05:05 Loc	21:54:46 Loc
Until	01:40:46	01:25:59
Duration	00:08:51	00:13:19
AOS Az.	107°	132°
Max El.	7°	22°
LOS Az.	21°	5°
Visual	Eclipse	Sun
Orbit #	382	4,814

Tracking Programs - Predict



What do *you* want to *do*?

- Just make a single satellite contact, just for the fun/challenge of it or to say “I did it”
- Make many CW / voice satellite contacts, grid square chasing, DX chasing, DXCC
- Send and receive data / packet BBS / APRS
- Experiment with digital signal processing
- Collect and analyze actual satellite telemetry
- Help build a satellite
- Perform ranging, satellite orbital mathematics

What I Do: Digital Signal Processing

- Reed Solomon / Viterbi decoder error detection *and correction*
- Same technology that NASA/JPL used on Voyager missions at outer planets
- Turbo codes (Phase 3E)
- Easy! All you need is a computer and a soundcard connected to your radio!

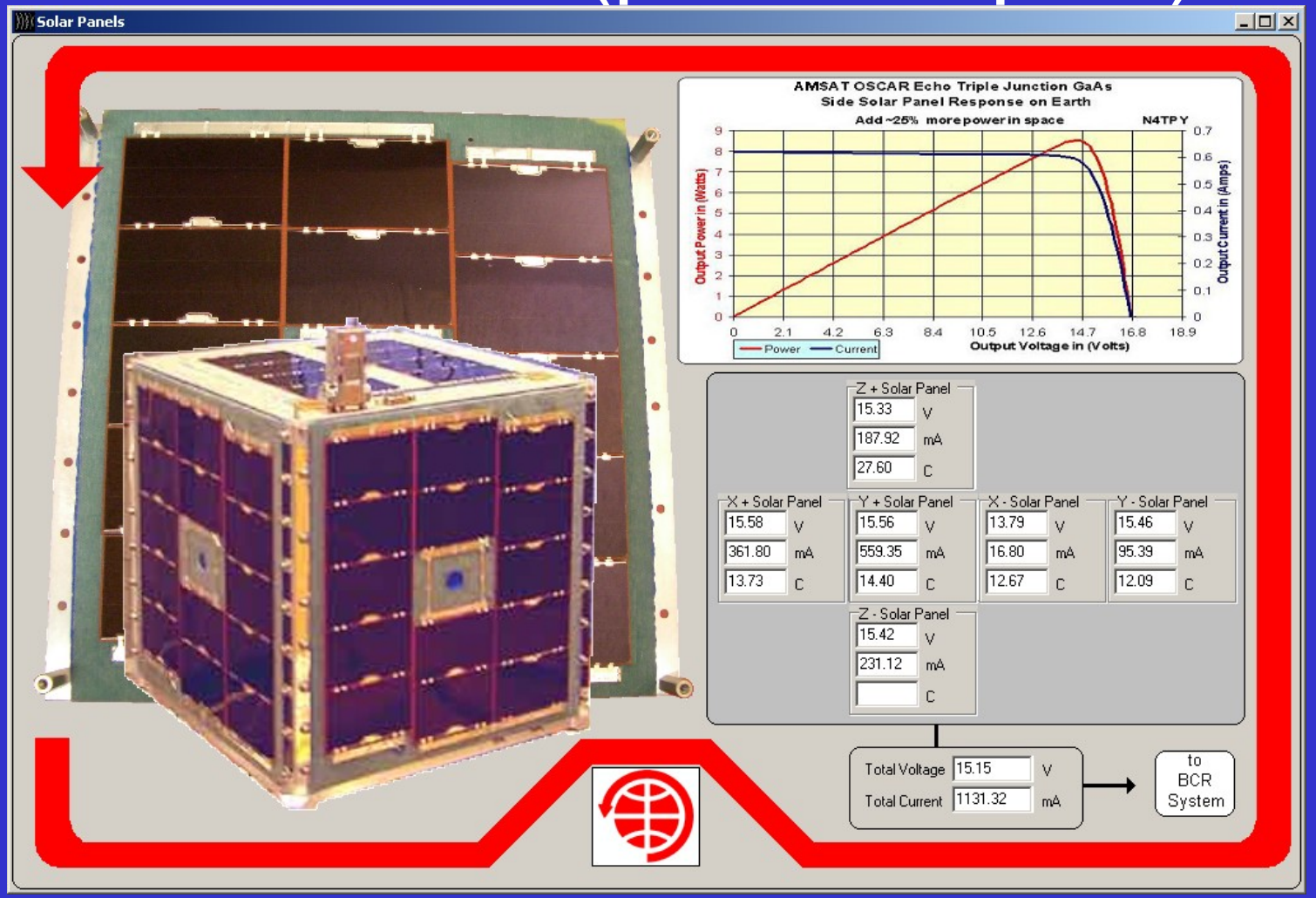
What I Do: Digital Signal Processing

- Moderate computer (any Pentium computer should work fine)
- Sound card
- Radios (you, *or your friends*, must have a radio)
- Download FREE software from the Internet
- Go!

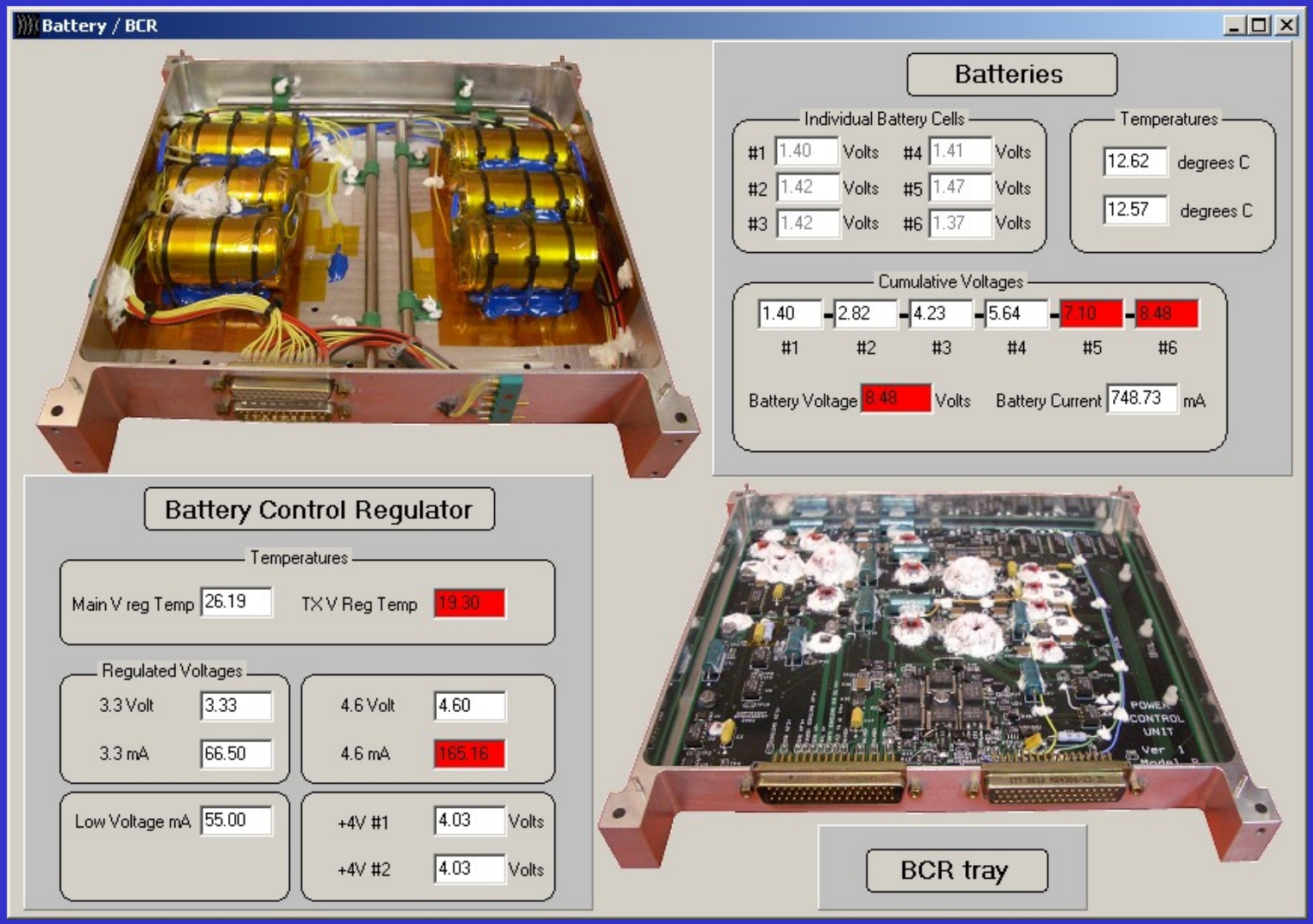
More Digital Signal Processing

- 9600 or 38400 baud reception with a sound card (no modem, no TNC)
- Audio from the radio goes to the sound card.
- DSP software takes the audio and “makes bits” to demodulate the data
- You decide what to do with the bits!

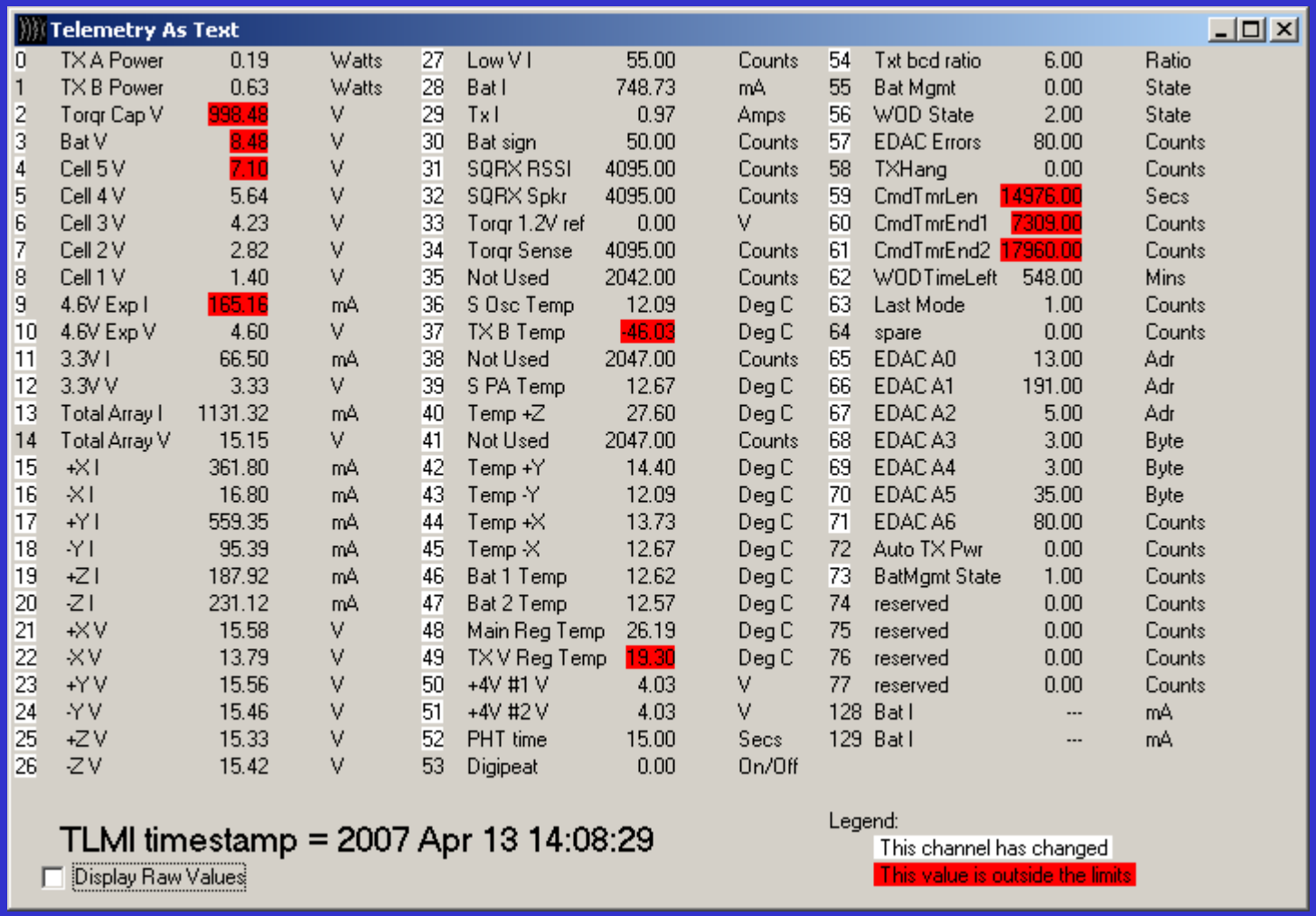
Analyzing Solar Panel Telemetry from AO-51 (power? spin?)



Analyzing Power Telemetry from AO-51 (batteries charged?)



Analyzing Telemetry from AO-51



Telemetry As Text

0	TX A Power	0.19	Watts	27	Low V I	55.00	Counts	54	Txt bcd ratio	6.00	Ratio
1	TX B Power	0.63	Watts	28	Bat I	748.73	mA	55	Bat Mgmt	0.00	State
2	Torqr Cap V	998.48	V	29	Tx I	0.97	Amps	56	WOD State	2.00	State
3	Bat V	8.48	V	30	Bat sign	50.00	Counts	57	EDAC Errors	80.00	Counts
4	Cell 5 V	7.10	V	31	SQRX RSSI	4095.00	Counts	58	TXHang	0.00	Counts
5	Cell 4 V	5.64	V	32	SQRX Spkr	4095.00	Counts	59	CmdTmrLen	14976.00	Secs
6	Cell 3 V	4.23	V	33	Torqr 1.2V ref	0.00	V	60	CmdTmrEnd1	7309.00	Counts
7	Cell 2 V	2.82	V	34	Torqr Sense	4095.00	Counts	61	CmdTmrEnd2	17960.00	Counts
8	Cell 1 V	1.40	V	35	Not Used	2042.00	Counts	62	WODTimeLeft	548.00	Mins
9	4.6V Exp I	165.16	mA	36	S Osc Temp	12.09	Deg C	63	Last Mode	1.00	Counts
10	4.6V Exp V	4.60	V	37	TX B Temp	-46.03	Deg C	64	spare	0.00	Counts
11	3.3V I	66.50	mA	38	Not Used	2047.00	Counts	65	EDAC A0	13.00	Adr
12	3.3V V	3.33	V	39	S PA Temp	12.67	Deg C	66	EDAC A1	191.00	Adr
13	Total Array I	1131.32	mA	40	Temp +Z	27.60	Deg C	67	EDAC A2	5.00	Adr
14	Total Array V	15.15	V	41	Not Used	2047.00	Counts	68	EDAC A3	3.00	Byte
15	+X I	361.80	mA	42	Temp +Y	14.40	Deg C	69	EDAC A4	3.00	Byte
16	-X I	16.80	mA	43	Temp -Y	12.09	Deg C	70	EDAC A5	35.00	Byte
17	+Y I	559.35	mA	44	Temp +X	13.73	Deg C	71	EDAC A6	80.00	Counts
18	-Y I	95.39	mA	45	Temp -X	12.67	Deg C	72	Auto TX Pwr	0.00	Counts
19	+Z I	187.92	mA	46	Bat 1 Temp	12.62	Deg C	73	BatMgmt State	1.00	Counts
20	-Z I	231.12	mA	47	Bat 2 Temp	12.57	Deg C	74	reserved	0.00	Counts
21	+X V	15.58	V	48	Main Reg Temp	26.19	Deg C	75	reserved	0.00	Counts
22	-X V	13.79	V	49	TX V Reg Temp	19.30	Deg C	76	reserved	0.00	Counts
23	+Y V	15.56	V	50	+4V #1 V	4.03	V	77	reserved	0.00	Counts
24	-Y V	15.46	V	51	+4V #2 V	4.03	V	128	Bat I	---	mA
25	+Z V	15.33	V	52	PHT time	15.00	Secs	129	Bat I	---	mA
26	-Z V	15.42	V	53	Digipeat	0.00	On/Off				

TLMI timestamp = 2007 Apr 13 14:08:29

Display Raw Values

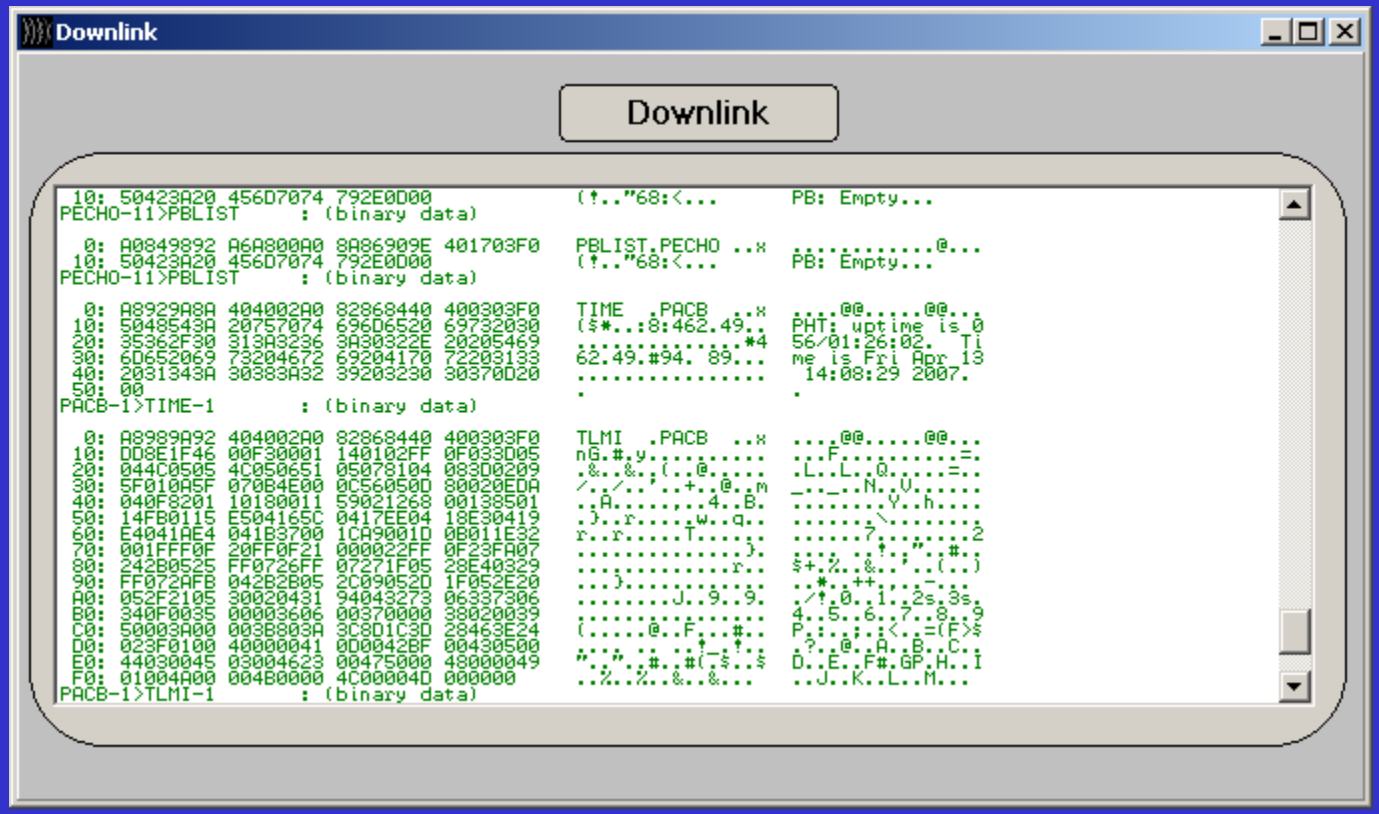
Legend:

This channel has changed

This value is outside the limits

AO-51 Telemetry

- Live telemetry data as transmitted from the satellite via radio or real time via the Internet or from the FTP archives (your choice)



Tips for satellites

- MOST IMPORTANT – Listen! The satellite WILL hear you – don't transmit if you can't hear the signal from it.
- Get a preamp – huge improvement.
- Practice receiver tuning because doppler will cause the signal's frequency to shift lower.
- Drop your callsign at just the right moment – this takes practice.

Tips for satellites

- Start with a simple station that will let you make contacts, then make your station better and fancier.
- If you want, you can avoid the “big gun” stations by carefully selecting passes by day-of-week, by time of day, and/or by who is in view of the satellite (hint: look at the footprint in the satellite tracking program)

Tips for satellites

- Before trying “Satellite/Mobile” set up your station at home. Verify you have all the parts and that they all work together. Then take it on the road.
- For working satellites while “mobile” (parked) from the back of your car, always carry an extra set of car keys so you won't get locked out. (Don't ask how I know this.)

The Future

- Suitsat 2 – Russian spacesuit “hand launched” from the International Space Station will contain radios and slow scan TV using an advanced software defined radio (SDR). Launch date: “soon”

NASA Photo

- Phase 3E and Eagle (high earth orbit with passes lasting several hours)

The Future

- Delfi-C3 (Launched! It's UP!)
- ISS – Columbus module (now in orbit!)
- KiwiSat (late 2008? - Modes UV, LV)
- Hawksat (late 2008?)
- “Go Mars” (Phase 5)
- IntelSat geostationary opportunity

??? Questions ???

What questions do you have?

? ? ?

Bonus Slide – Internet Links

- AMSAT website: www.amsat.org
- Keplerian Elements mailing list: http://www.amsat.org/mailman/listinfo/keps
- K3TZ patch antenna with PDF / CAD drawings: http://www.qsl.net/k3tz/index.html
- Cheap Yagis: http://www.wa5vjb.com/references.html
- 435 Quagi: Dec 1987 QST magazine
- Suitsat: www.suitsat.org

Bonus Slide #2 – More Internet Links

- Cardboard Aluminum foil 2.4 GHz horn antennas: http://www.barc.org/ao40_antennas/rxantenna.html
- Cardboard Aluminum foil 435 MHz transmit antenna: http://www.barc.org/ao40_antennas/txantenna.htm (note: URL ends in htm not html)
- www.downeastmicrowave.com
- Willow and Sabins: http://members.aol.com/dquagliana/willow/WillowSabins.zip