Wide Band Antennas for Low Profile DXing and RadioSport

2008 June 24

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prepared for

W4BUG

GCARA
Amateur Radio Club
PO Box 456
Pompano Beach, FL. 33303

Based on "All Band Attic Antenna"
QST October 2007

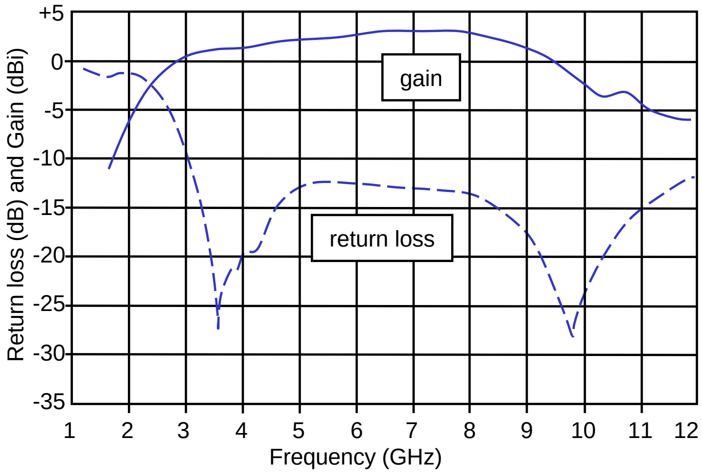
Broad Band elements Key to an Indoor Antenna

- **Key principles of Broad banding**
  - fat dipole elements are wide band
  - wire cages look fat
- **Principles applied to an indoor antenna**
  - attic antenna construction
  - a peek in the attic
  - a cool way to measure antenna gain
- **RF Exposure Safety and Indoor Antennas**
  - extensive near field analysis using NEC
  - various techniques compared

"Fat" Elements are broad-band

<u>Example</u>:
2-cent UWB antenna:

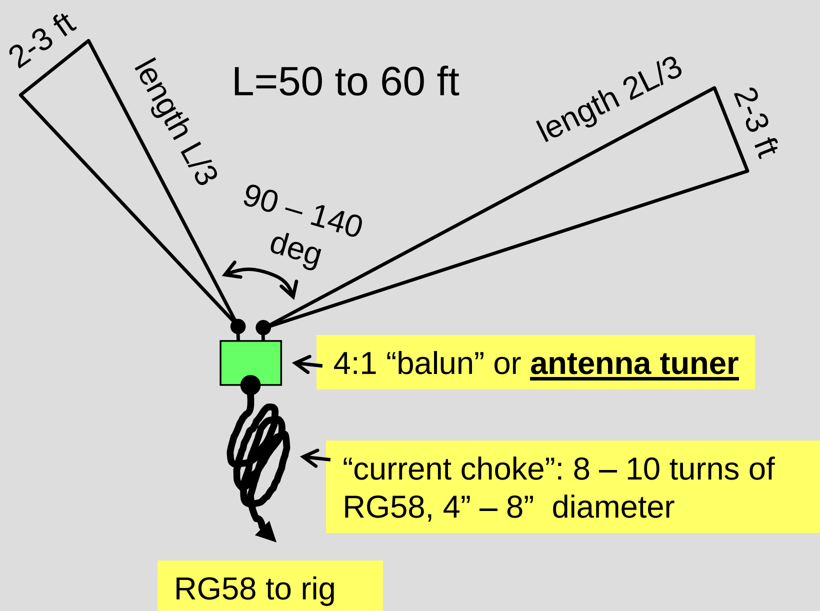
- 3 to 1 bandwidth
- "Tame" impedance *vs.* frequency



K. Siwiak and Y. Bahreini, *Radiowave Propagation and Antennas for Personal Communications, 3rd Edition*, Artech House: MA, 2004

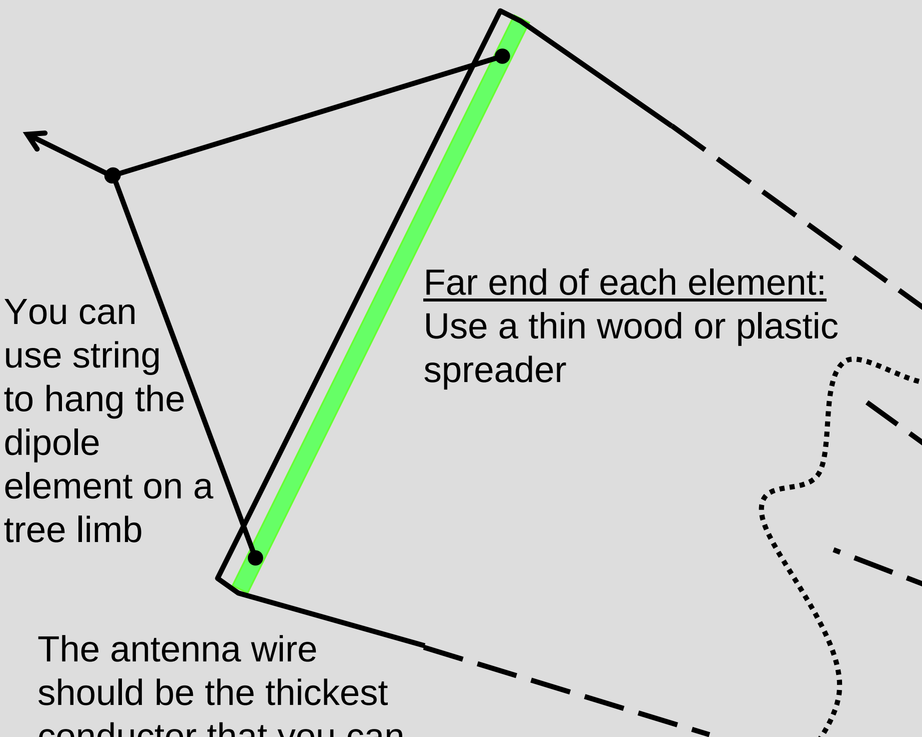
One Approach to a Broad-band antenna

Dipole elements are “***wire cages***” for broad-banding



- **Fat elements**
  - “cage” design … outline of a wide ribbon / bowtie
- **Current choke**
  - to isolate feed line … keep RF out of shack
- **Automatic tuner**
  - for wide band match
- **Safety ground**
  - for lightning protection

Some mechanical details



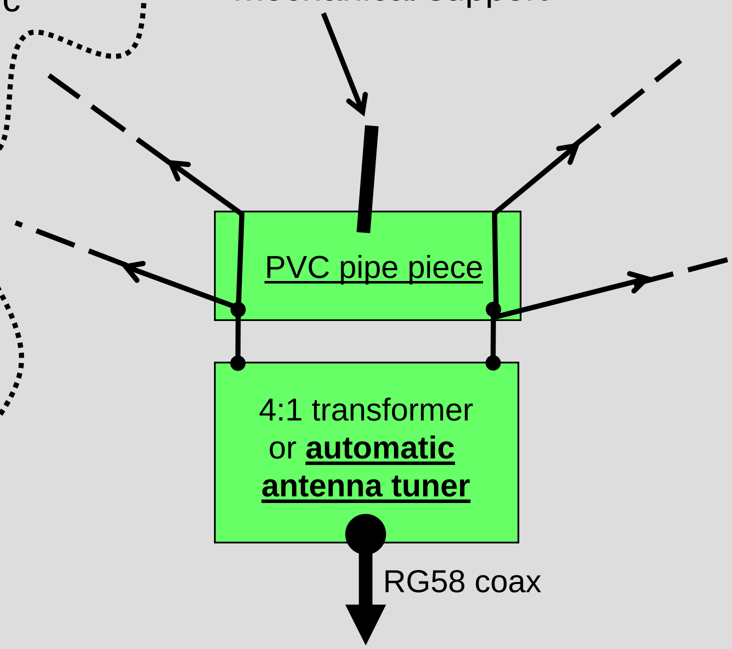
Far end of each element:
Use a thin wood or plastic spreader

You can use string to hang the dipole element on a tree limb

The antenna wire should be the thickest conductor that you can practically find... stranded dipole wire, or even insulated wire.

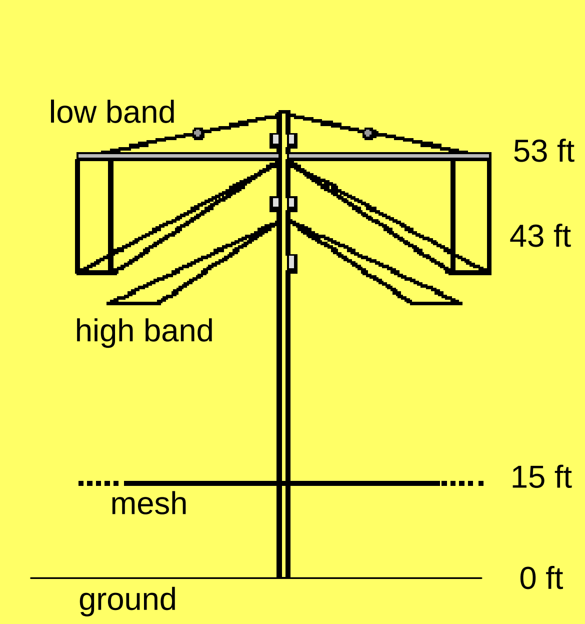
At the dipole feed point:

use the 4:1 balun as a support if it is strong enough, or else use a piece of PVC pipe as a mechanical support



HF "Wire Cage" used by HAARP

HAARP comprises dipole antennas above a wire mesh ground screen, [*array used in recent EME experiment at 6.8 MHz*]



Low band covers 2.8 – 7.6 MHz

High band covers 7.6 – 10 MHz

Array of 180 masts, each with crossed dipole pairs, capable of 3,600,000 watts transmitter power!

Dipole elements "fattened" through the use of a *wire cage design ...* impedance bandwidth of the dipoles is increased significantly

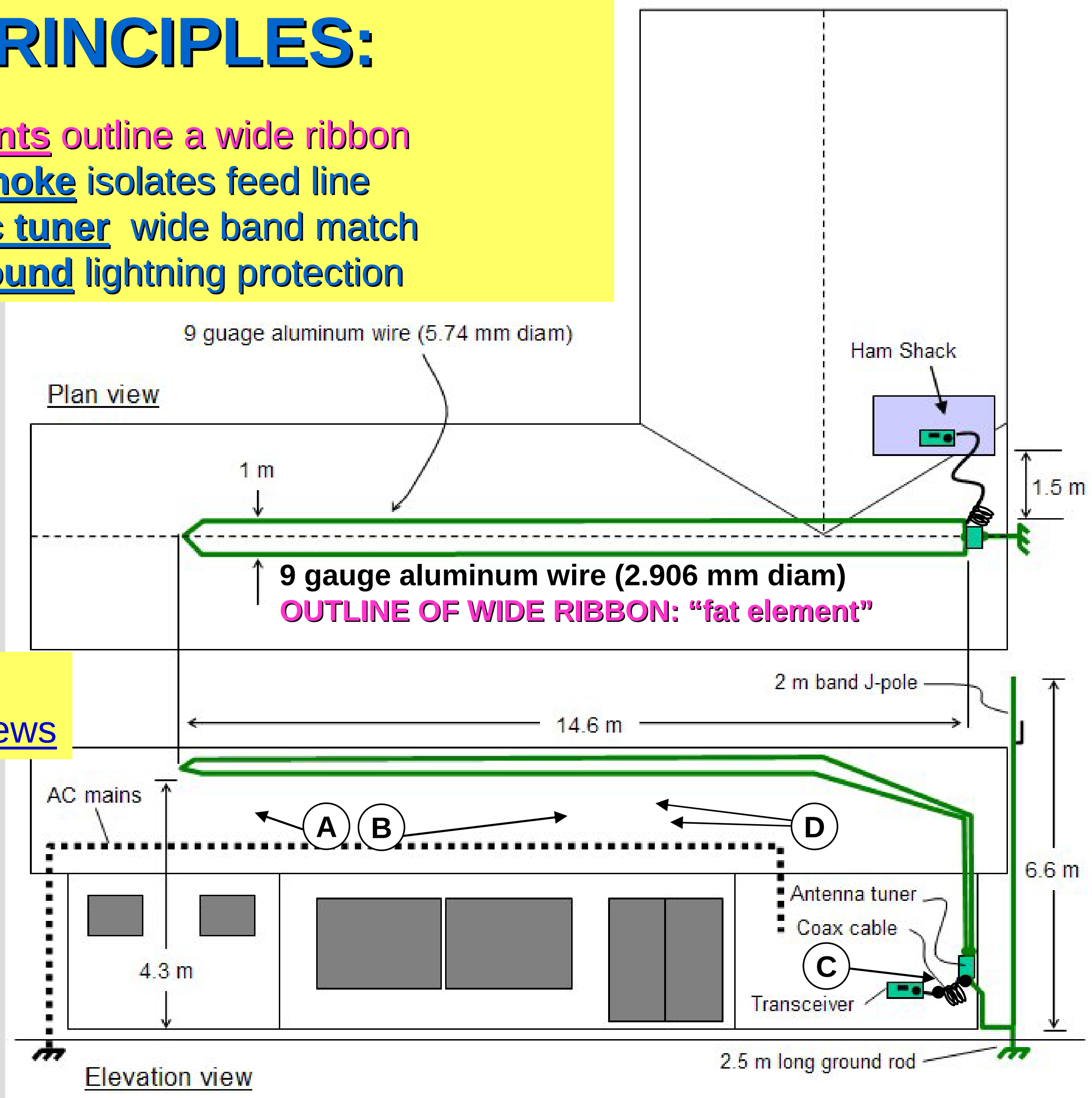
http://haarp.alaska.edu/haarp/ant.html

High Frequency Active Auroral Research Program, Gakona, Alaska

Applying Broad Band Principles to an Indoor Antenna

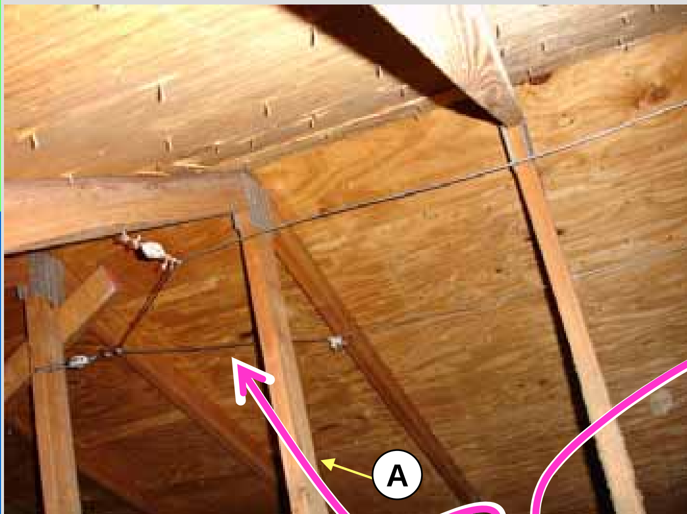
KEY PRINCIPLES:

- **Fat elements** outline a wide ribbon
- **Current choke** isolates feed line
- **Automatic tuner** wide band match
- **Safety ground** lightning protection



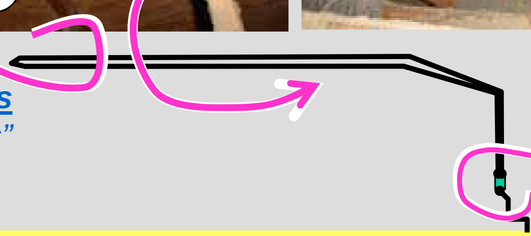
A B C D are photo views

In the attic ...



<A-ke4pt-attic.JPG>

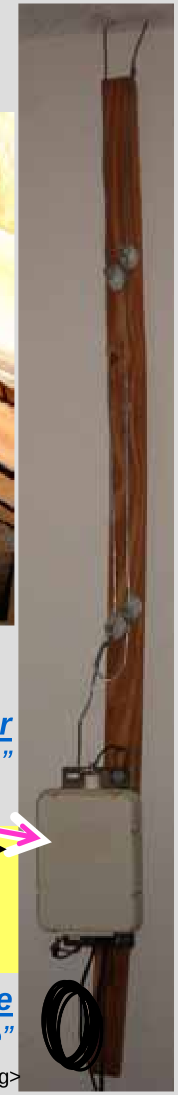
<B-ke4pt-attic.JPG>

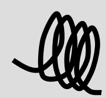


"__Fat elements__
'tame' the impedances"

"__Automatic tuner__
for wide band match"

- Ribbon outline suspended by egg insulators
- Ham shack 6 ft to the left of the AH-4 tuner

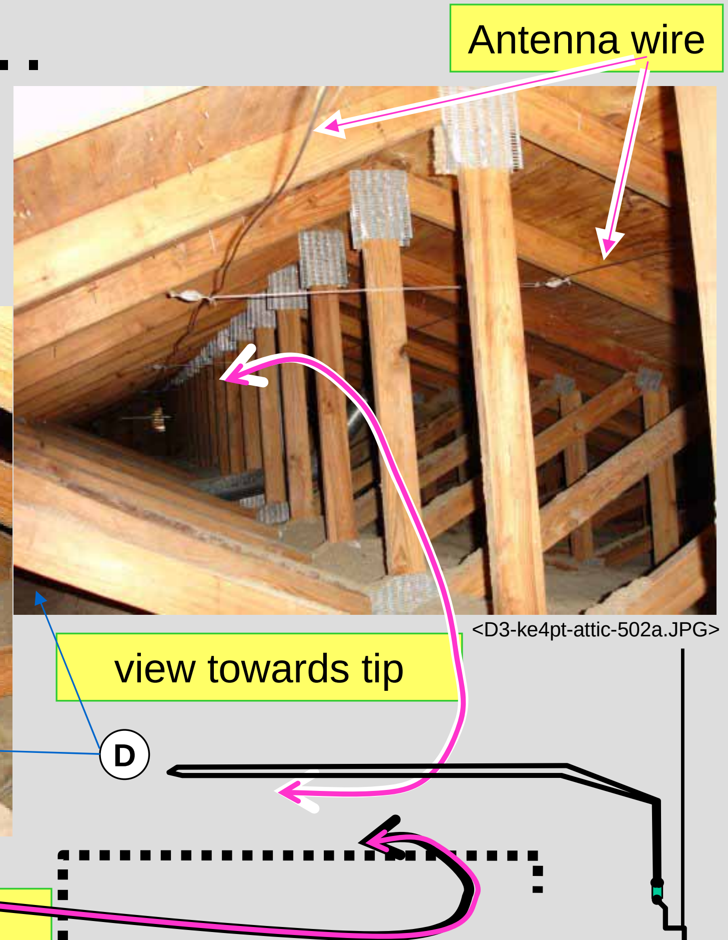




"__Current choke__
isolates the feed line"

<C-ke4pt-Match-feed.jpg>

But not alone ...



<D3-ke4pt-attic-502a.JPG>

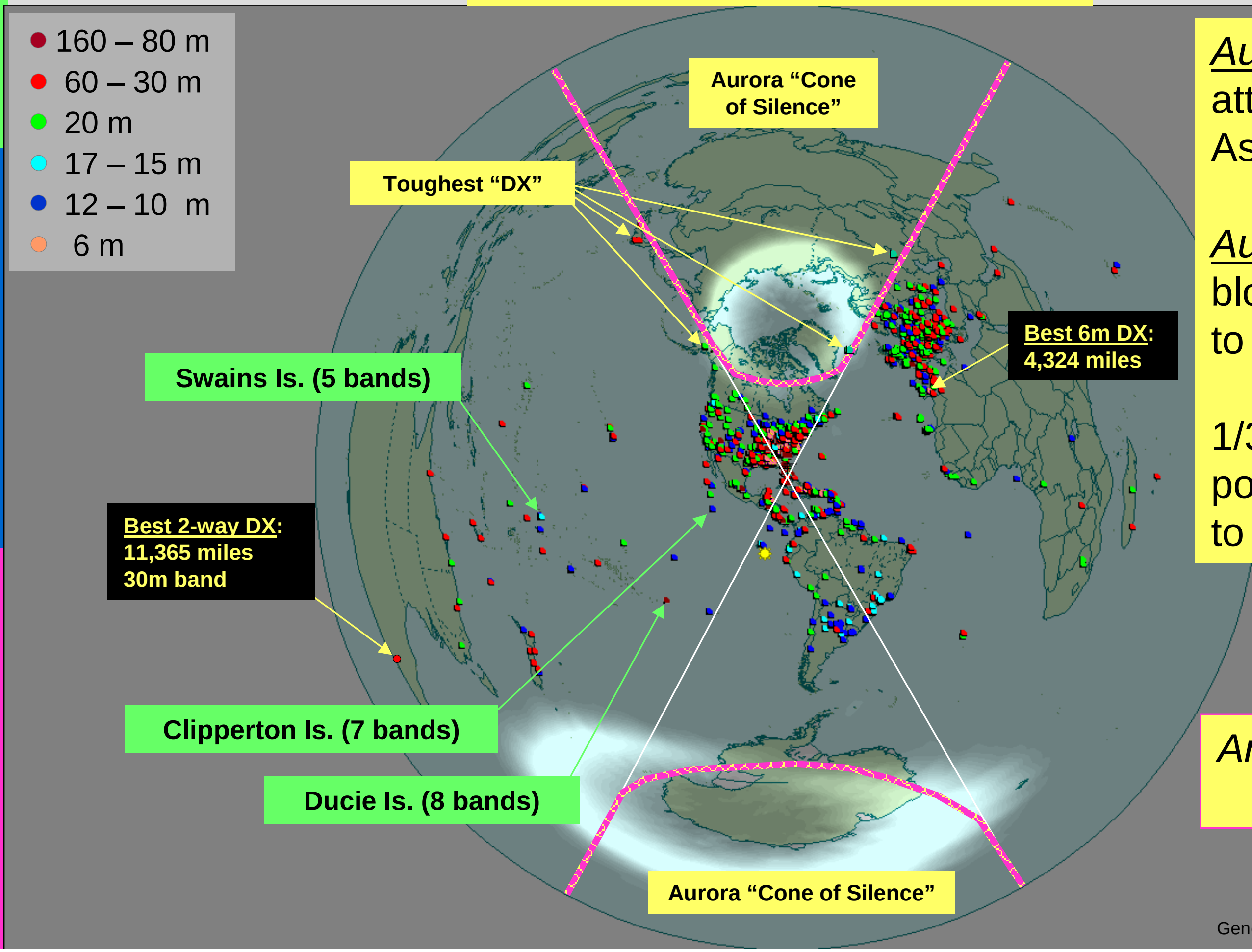

<D2-ke4pt-attic-503a.JPG>

- AC-mains conduit parallels antenna elements
- Also: AC distribution and phone lines

How the Indoor Antenna Performs

QSOs from Southern Florida cover the Earth ... (almost)

All QSOs: 160m through 6m



Aurora Borealis attenuation makes Asia QSOs difficult

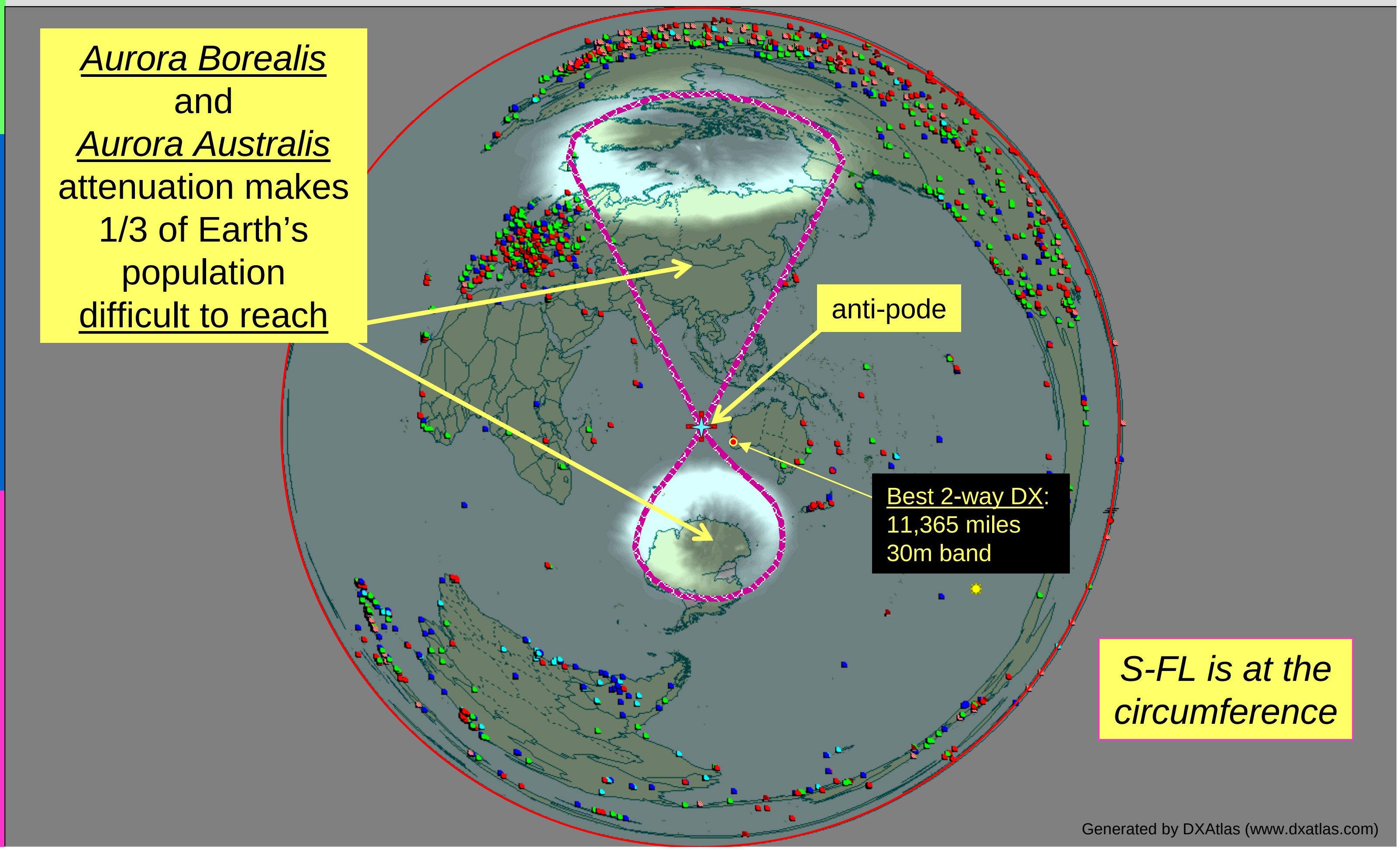
Aurora Australis blocks ***long path*** to Asia

1/3 of Earth's population difficult to reach

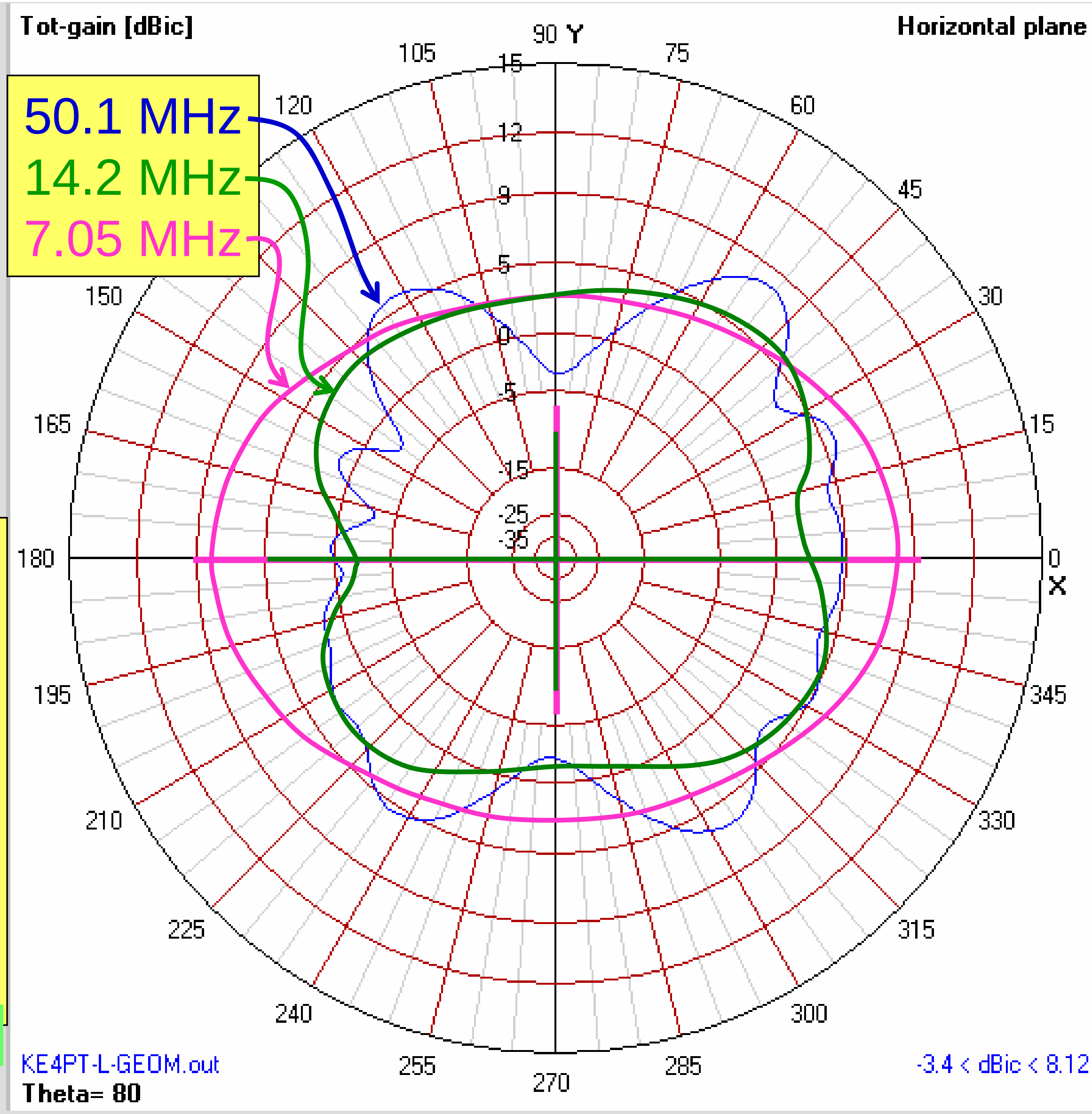
Anti-pode is at the circumference

Generated by DXAtlas (www.dxatlas.com)

View from the Anti-pode



Nearly Omni-Patterns



At 20 deg elev:

Pattern ripple is -3.4 – +8.1 dBiC

... just 2 S-units

Patterns generated by 4nec2 (home.ict.nl/~arivoors/)

LoTW "Spot to QSL": KL7J in 49 minutes!

DXCC: 173 worked / 152 confirmed

band:	160	80	60	40	30	20	17	15	12	10	6
W'KD:	2	22	1	98	68	120	92	73	15	41	14
CONF:	2	12	1	51	35	83	65	44	9	22	14

WAS: awarded, with 27 worked / 26 confirmed on 6m

	AK	AL	AR	AZ	CA	CO	CT	DE	FL	GA	HI	IA	ID	IL	IN	KS	KY	LA	MA	MD	ME	MI	MN	MO	MS	MT
160M			C							C					C											
80M					C	C														C						
60M																										
40M	C	C		C	C				C	C		C		C	C	C	C		C	C		C			C	
30M							C			C		C												C		
20M			C	C	C	C	C	C	C			C	C	C	C	C		C	C	C		C		C	C	C
17M				C					C												C	C	C			
15M				C	C		C		C	C	C								C	C	C	C	C			
12M											C															
10M									C	C									C	C						
6M		C	C				C	C	C	C				C	C		C	C		C				C	C	
ALL	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

	NC	ND	NE	NH	NJ	NM	NY	NV	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VA	VT	WA	WI	WV	WY	wkd	cfm
160M	C									C						C									13	6
80M				C	C		C					C		C									C		15	10
60M														C											7	1
40M	C			C	C		C		C			C			C	C	C					C	C		36	26
30M		C	C			C										C									23	8
20M			C	C	C		C	C		C	C	C	C			C	C	C	C	C	C	C			47	35
17M				C	C				C								C								23	9
15M	C		C		C		C							C	C		C							C	30	19
12M																									2	1
10M									C			C				C	C								22	8
6M	C				C		C		C	C		C	C	C		C	C		C			C	C		27	26
ALL	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	50	50

F6EXV

Sked

QSOs by mode, 23 June 2008:

DXCC: 173 worked / 152 confirmed

band:	160	80	60	40	30	20	17	15	12	10	6
W'KD:	2	22	1	98	68	120	92	73	15	41	14
CONF:	2	12	1	51	35	83	65	44	9	22	14

CW QSOs: 167 worked / 139 confirmed

band:	160	80	60	40	30	20	17	15	12	10	6
W'KD:	2	21	0	95	68	114	78	51	10	17	9
CONF:	2	12	0	50	35	69	58	29	8	9	7

SSB QSOs: 96 worked / 67 confirmed

band:	160	80	60	40	30	20	17	15	12	10	6
W'KD:	1	4	1	8	0	55	40	49	7	35	11
CONF:	1	2	1	4	0	33	18	25	3	17	10

CW vs. SSB:

With a maximum of 100 watts PEP from the transmitter, CW average power is 40 watts, but with SSB it is only 20 watts (3 dB advantage for CW). At the receiver end of the propagation link the CW receiver noise bandwidth is typically 300 Hz compared with 2,700 Hz for SSB (9.5 dB more for CW). Finally, CW operators appear to listen more intently to CW, especially experienced DXpedition operators, perhaps tolerating 6 dB SNR whereas comfortable SSB listening needs 10 dB SNR (another 4 dB for CW). Thus, there is up to 16.5 dB net advantage for CW over SSB, equivalent to about 3 S-units! Similar advantages can be claimed for the narrow band digital modes.

Result:

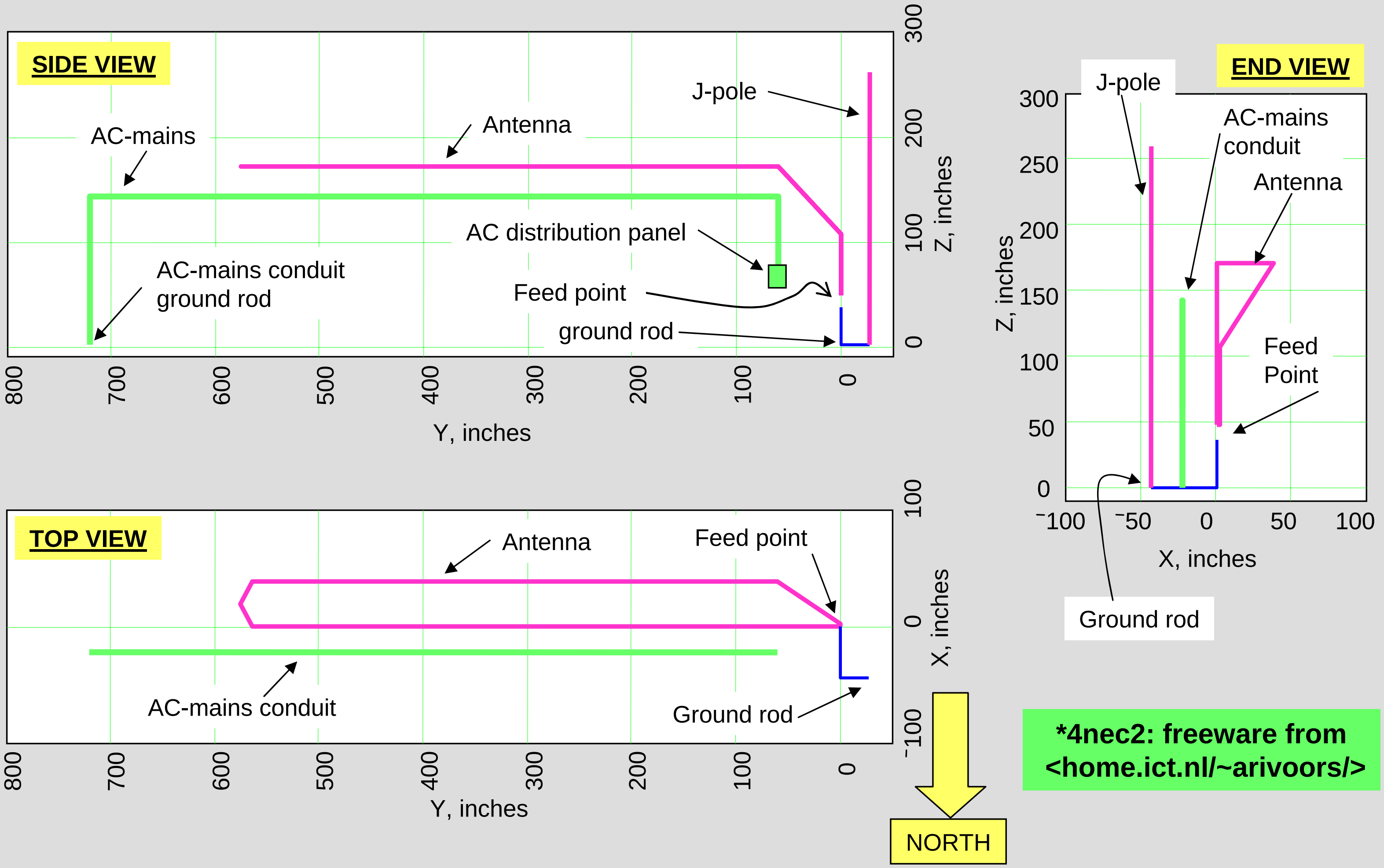
lots of nice “wall paper”

SP7AID
São Tomé & Príncipe
West Africa
S9SS
THE AMERICAN
RADIO RELAY LEAGU
WAS
MJ/K8PT
HKØGU/1 Colombia
VU7RG VU7MY
International Amateur
Radio Union
WAC
WORKED ALL CONTINENTS
KE4PT
VQ9LA
DIEGO GARCIA
V73NS
Kwajalein Atoll
1AØKM
8N1EME
9Q1EK
BASIC
The American Radio Relay League
DX CENTURY CL
This Certifies that
Kai Siwiak, KE4PT
GD6IA
Isle of Man
5A7A
KL7J
Alaska
#41,352
Norfolk Island
VK9DNX
N8S
SWAINS ISLAND DXPEDITION
SWAINS ISLAND
5W5AA
KH8/N9YU
TC0DX
IOTA DXPEDITION EU-186

RF Safety and Indoor Antennas

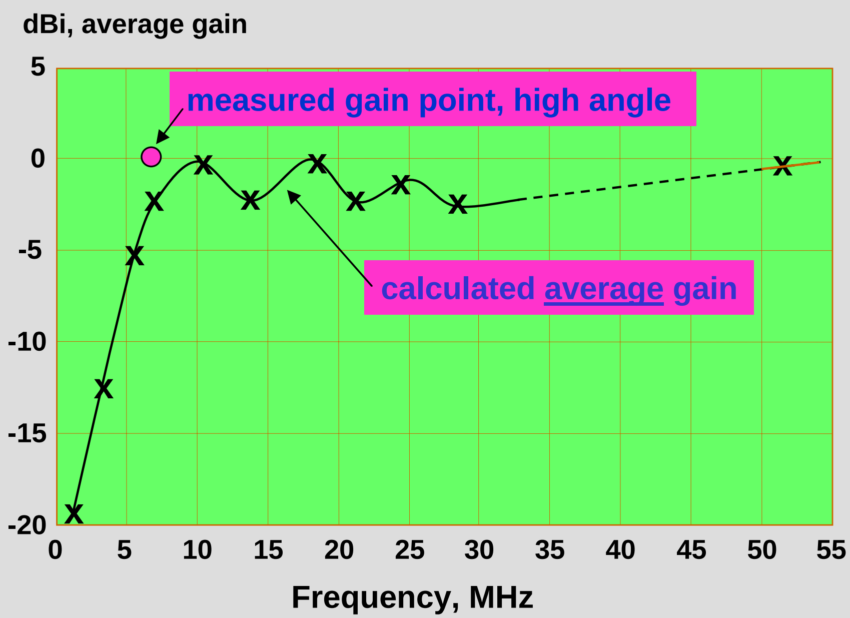
- NEC used to calculate gain, patterns, near fields
- NEC3 and NEC2 used for RF exposure analysis
- Other RF exposure estimates also compared

Antenna Modeled in NEC*



***4nec2: freeware from <home.ict.nl/~arivoors/>**

Average Gain (Calculated)



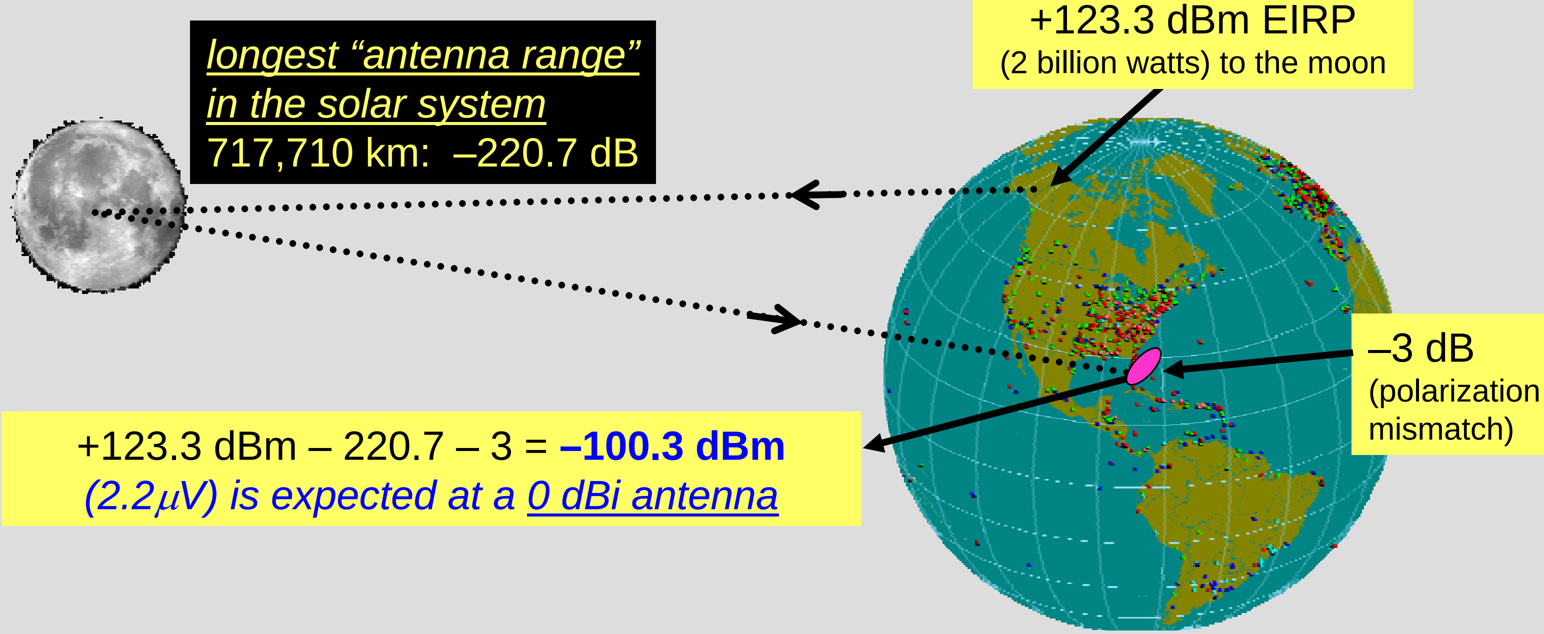
Modeled with NEC3
using real ground
(courtesy of Bill Guy, W7PO)

ε=15, σ=0.015 mho/m

Largest antenna dimension is:
0.09λ at 1.8 MHz
0.36λ at 7 MHz

$$Average\,Gain = 10\log\left(\frac{Power\ Radiated}{Transmitter\ Power}\right) = Radiation\ Efficiency$$

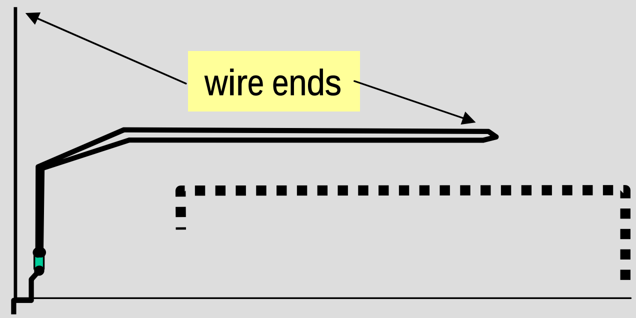
Cool Way to Measure Antenna Gain



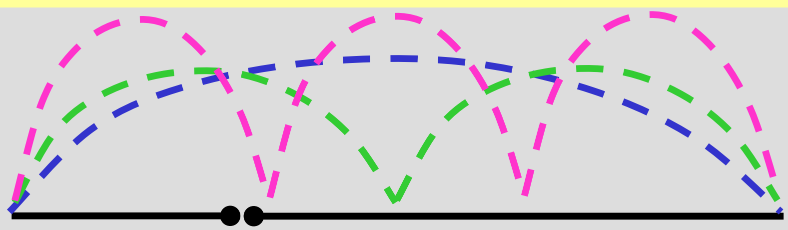
Actual signals reported by KE4PT to HAARP: –100 dBm, so KE4PT antenna gain is [–100 –(–100.3)] = **+0.3 dBi at 6.8 MHz!**

This is my longest distance antenna gain measurement yet, beating the 300 to 2,200 km Space Shuttle Columbia window antenna gain measurements for SAREX during STS-55 [QST, Oct 1993 pp 53-55]

EM analysis



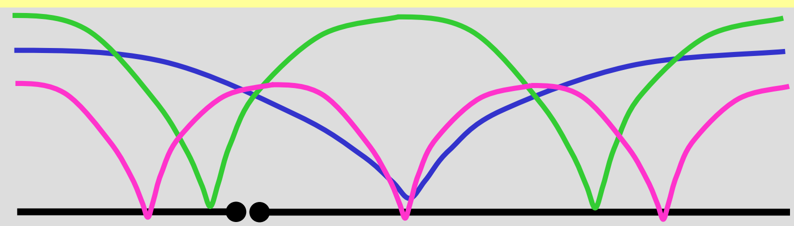
Antenna <u>currents</u> are ZERO at wire ends:



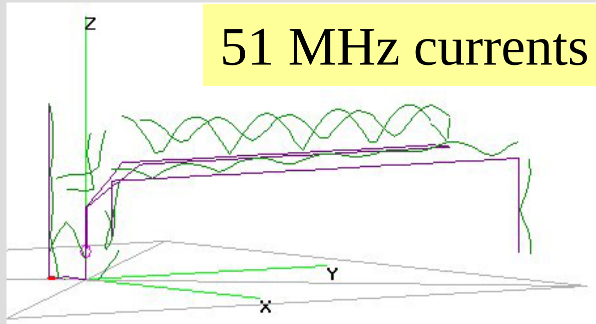
Magnetic Fields are due to *<u>currents</u>*

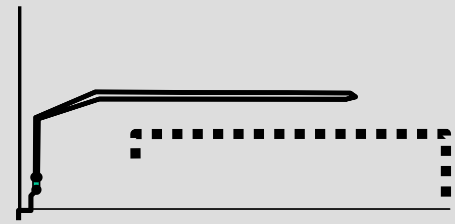
Antenna <u>voltages</u> are MAXIMUM at wire ends:

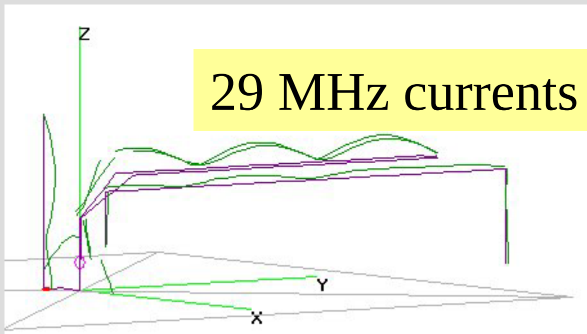
Electric Fields are due to *<u>voltages</u>*

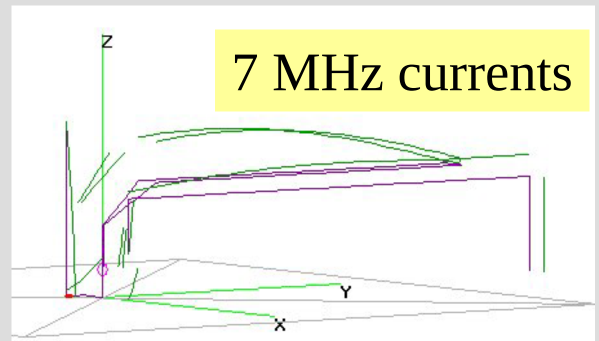


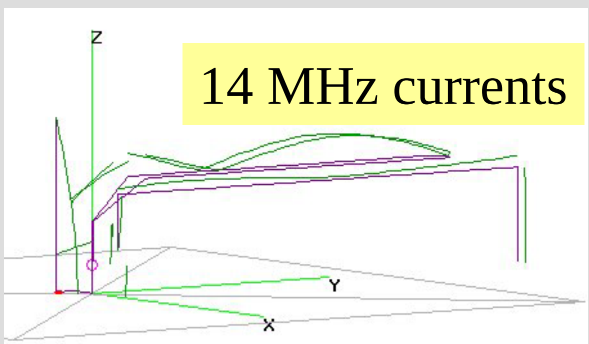
RF safety analysis

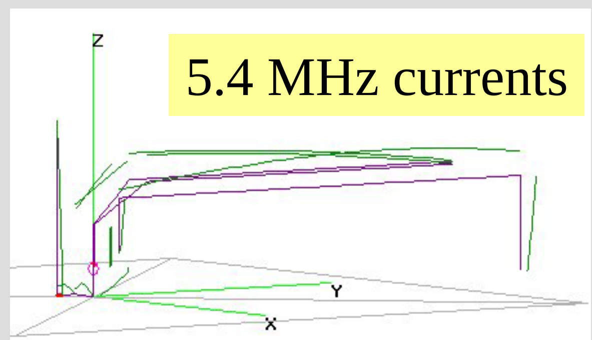




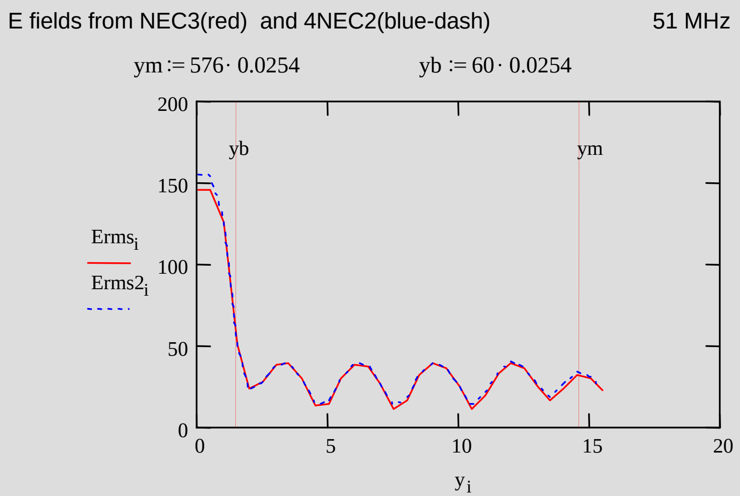


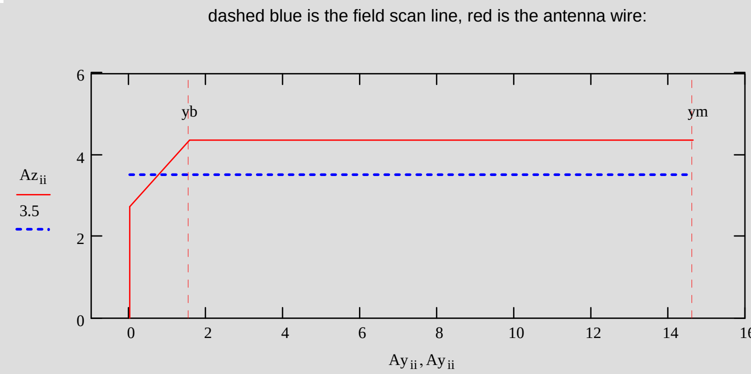


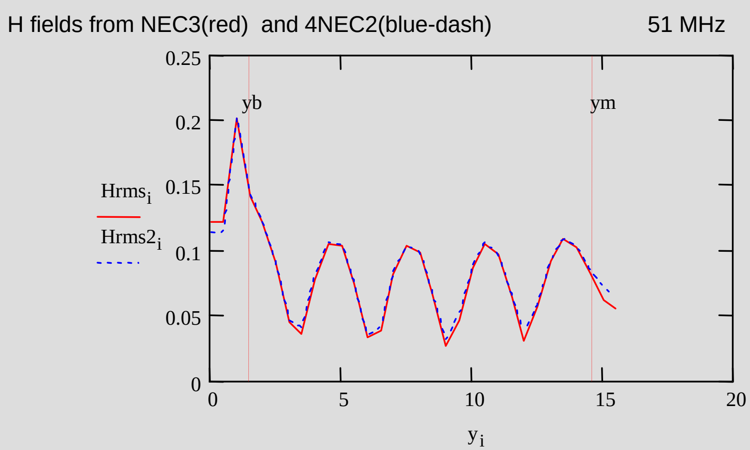




NEC2 vs. NEC3: near fields







51 MHz, scan in y at z = 3.5 m

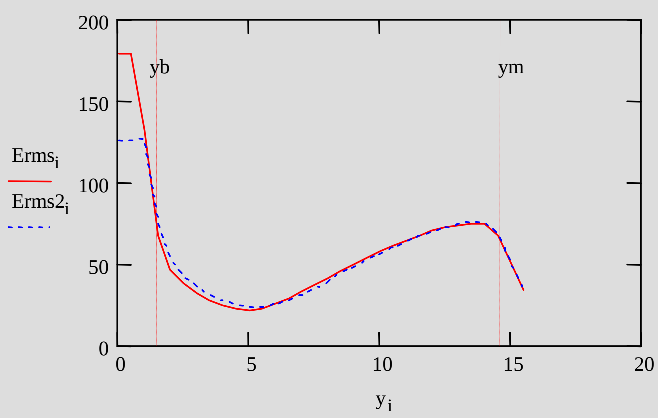
NEC3 correctly handles buried wires and ground posts

NEC3 uses “real ground” and correctly models ground connections: <u>courtesy of Bill Guy, W7PIO</u>

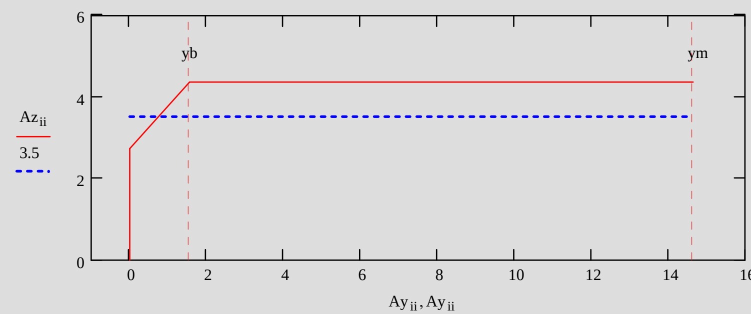
NEC2 vs. NEC3: near fields

E fields from NEC3(red) and 4NEC2(blue-dash

$ym := 576 \cdot 0.0254$ $yb := 60 \cdot 0.0254$

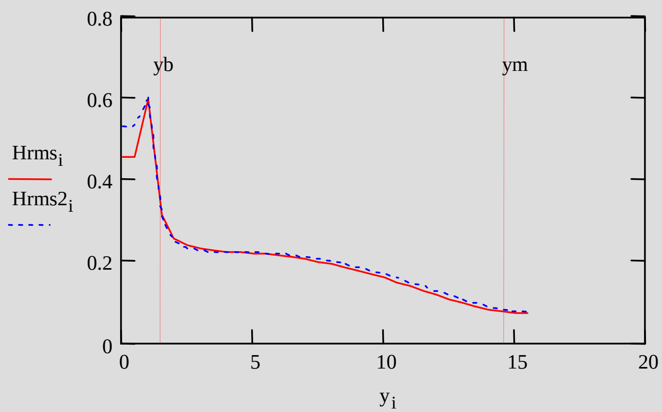


dashed blue is the field scan line, red is the antenna wire:



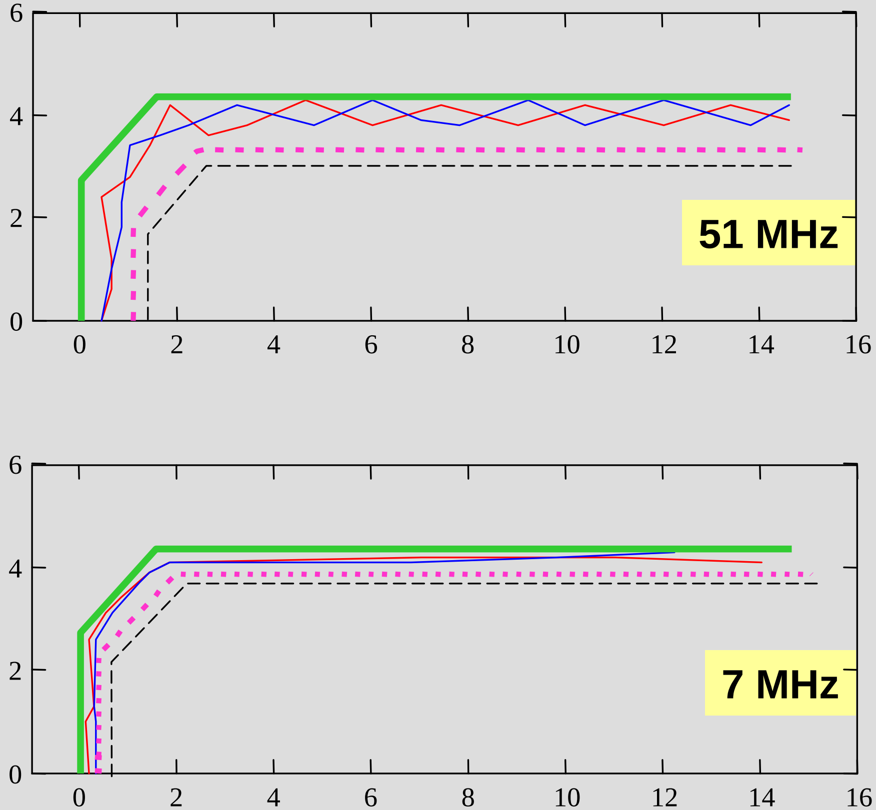
7 MHz, scan in y at z = 3.5 m

H fields from NEC3(red) and 4NEC2(blue-dash



NEC3 and NEC2 give same results except at wires near the ground post

RF Exposure:
Compliance Distance



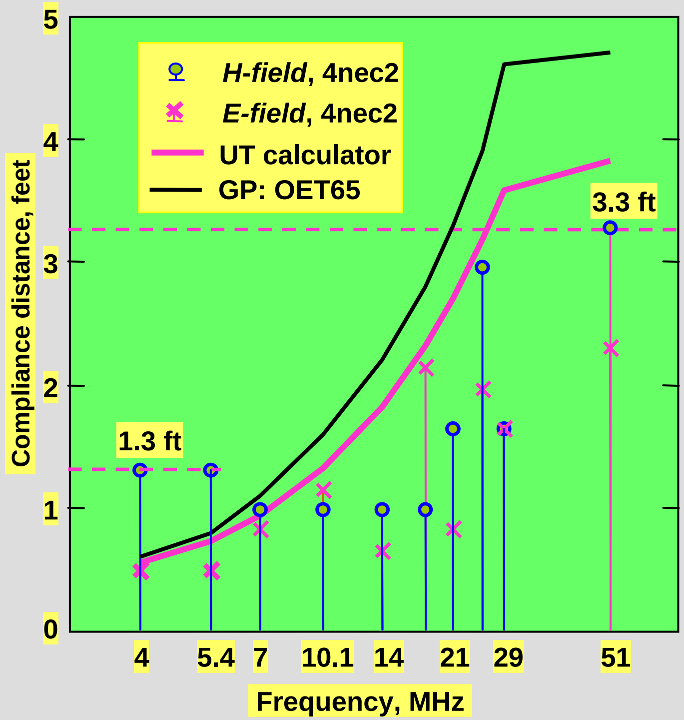
E (red) and H (blue) peaks are out of phase with each other, as expected

Multiple techniques used:

100 W, 100% duty, controlled space

Red: E-field NEC2
Blue: H-field NEC2
Mag: UTexas, "2.2 dBi no gnd"
Blk: OET65 general purpose

RF Safety Summary

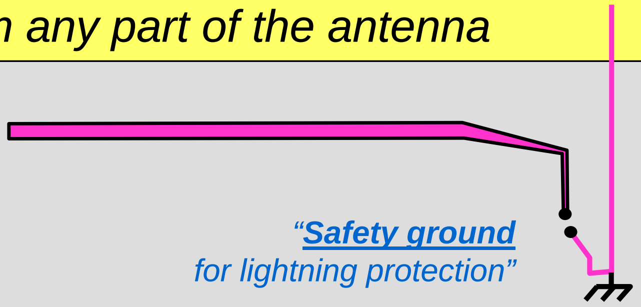


Extensive analysis using NEC2 & NEC3
Employed multiple techniques

RF Safety compliance distance for key-down 100 W is:

- 3.3 ft on 6 m band
- 1.3 ft on 80 m band

from any part of the antenna



RF Safety Resource

You obtain or renew your ham license using FCC form 605. By signing the form you agree to (among other things) the following fine-print text:

- **"I certify that … I have read and WILL COMPLY with Section 97.13(c) of the Commission's Rules regarding RADIOFREQUENCY (RF) RADIATION SAFETY and the amateur service section of OST/OET Bulletin Number 65."**

All needed resources can be found at: **< http://www.arrl.org/news/rfsafety/ >**

For most common antennas, one simple and effective way to do a station evaluation is by using the RF Safety Calculator at:

< http://n5xu.ece.utexas.edu/rfsafety/ >

Fill in the blanks, calculate, and print an archive copy for your log book!

For additional help, please contact me at **< ke4pt@amsat.org >**

-Kai, KE4PT, ARRL RF Safety Committee

Thanks for your kind attention!

- Wide-banding principles and indoor antennas
  - efficient on 6m to 80m, usable on 160m
  - omni-directional ±2 S-units
- Good performance
  - earned DXCC, WAS, WAC on an indoor antenna
  - *cool gain measurement validates the analysis!*
- Extensive RF Safety Analysis
  - NEC3, NEC2, other methods compared
  - simple approximate techniques give safe results

- ***QUESTIONS?*** ***ke4pt@amsat.org***

Dai, KE4QXL, daughter of KE4PT, just received her Master's degree for Stanford University

She's shown here contemplating the Stanford "Big Dish" antenna

No, it won't fit in dad's attic!

