SIGNAL SAFARI
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Warm up: How many antennas are in this room?

Dr. David C. Burnett
Department of Electrical and Computer Engineering
Villanova University
david.burnett@villanova.edu
lab.davidburnett.org

IEEE Region 1+2
Together building a better tomorrow

VILLANOVA ENGINEERING

Agenda

Part I -- 9:00 AM to 10:30 AM

- Antennas and radios
- Building a "2 m" antenna
- Testing antenna with a software-defined radio

Break -- 10:30 AM to 10:45 AM

Part II -- 10:45 AM to 12:15 PM

- On safari!

SDR test (preview)

- Installation instructions:

`https://github.com/alanbjohnston/CubeSatSim/wiki/sdrpp-setup-for-windows`

- General SDR++ binary downloads: sdrpp.org
- Recommendation: Each team runs two SDRs
  - One SDR uses an omnidirectional antenna for survey
  - One SDR uses our directional antenna for direction finding

SIGNAL SAFARI: PART I

(Instructor background slides removed to make a smaller download)

How many antennas are in this room?

- 30ish people?
- Phones, laptops, headphones, watches, hardware that is part of the room…

How many antennas are in this room?

- 35 people + infrastructure
- 35 people: 1 phone, 1 laptop each; assume one antenna each
  - Probably an under-count; different antennas for cellular vs. Wifi, plus MIMO
- Assume everyone has wireless headphones, half of which are wireless earbuds (1 antenna per earbud): 16 headphones + 19 earbuds
- Say 10 of us have smart watches
- Wi-Fi: assume 2 antennas per access point, 2 access points
- A/V stuff hidden (2 antennas?)

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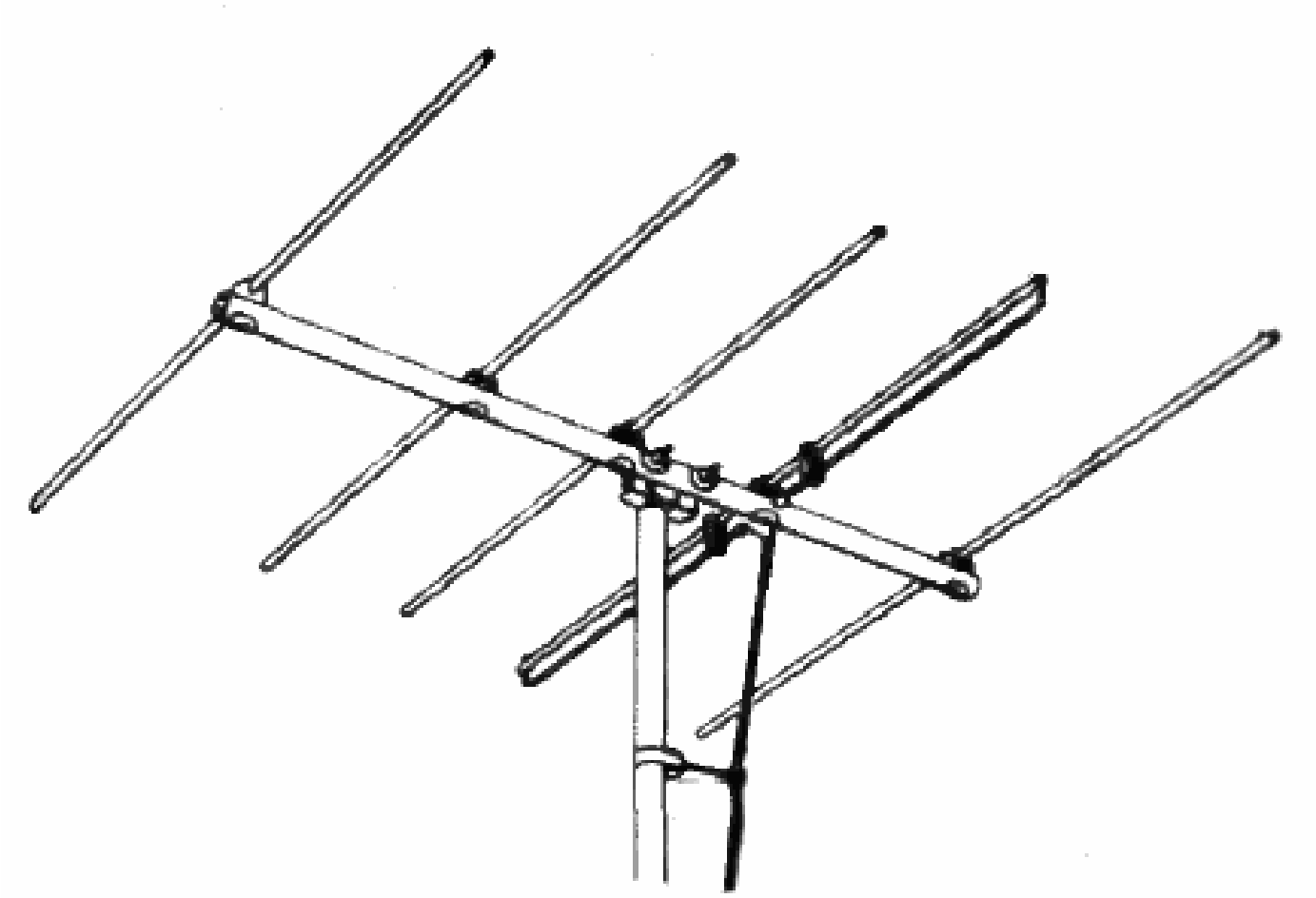
- A/V stuff hidden (2 antennas?)
- Grand total: 35*2 + 16 + 19*2 + 10 + 4 + 2 = 140
- Not counting extra wireless devices: tablets and tablet pens, wireless medical devices, smart rings, smart coffee cups…

Purpose of an antenna?

- Our radios will probably work OK without one, so why bother?
- Distinguish radio (electronics) from antenna (piece of metal)

The Yagi-Uda Array



https://upload.wikimedia.org/wikipedia/commons/7/74/Yagi_TV_antenna_1954.png

The Yagi-Uda Array

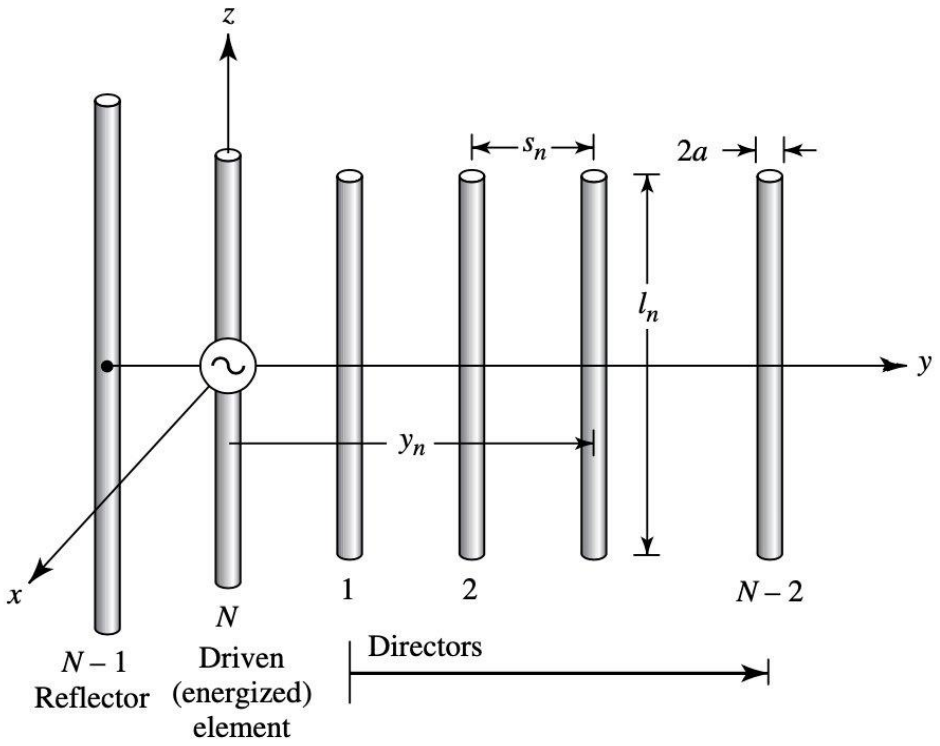


Figure 10.19 Yagi-Uda antenna configuration.

C. A. Balanis, *Antenna Theory: Analysis and Design*, 3rd ed., New York, NY, USA: Wiley-Interscience, 2005.

Antenna directivity: why do we want this?

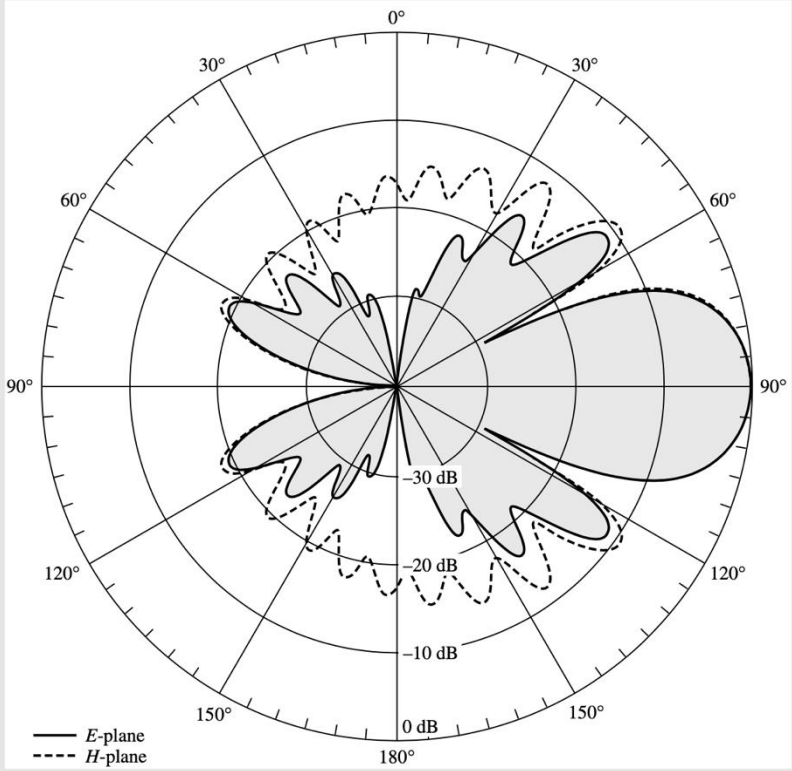


Figure 10.21 *E*- and *H*-plane amplitude patterns of 15-element Yagi-Uda array.

C. A. Balanis, *Antenna Theory: Analysis and Design*, 3rd ed., New York, NY, USA: Wiley-Interscience, 2005.

Antenna directivity (different antenna)

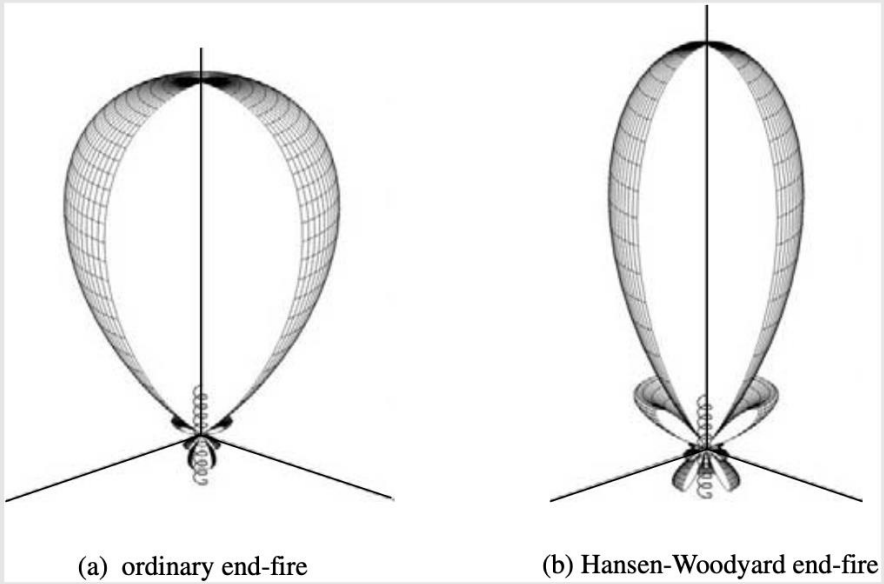


Figure 10.16 Three-dimensional normalized amplitude linear power patterns for helical *ordinary* ($p = 0.8337$) and *Hansen-Woodyard* ($p = 0.8012$) end-fire designs.

C. A. Balanis, *Antenna Theory: Analysis and Design*, 3rd ed., New York, NY, USA: Wiley-Interscience, 2005.

Yagi-Uda Design Table

TABLE 10.6 Optimized Uncompensated Lengths of Parasitic Elements for Yagi-Uda Antennas of Six Different Lengths

$d/\lambda = 0.0085$		Length of Yagi-Uda (in wavelengths)					
$s_{12} = 0.2\lambda$		**0.4**	**0.8**	**1.20**	**2.2**	**3.2**	**4.2**
LENGTH OF REFLECTOR (l_1/λ)		**0.482**	**0.482**	**0.482**	**0.482**	**0.482**	**0.475**
LENGTH OF DIRECTORS, λ	l_3	0.442	0.428	0.428	0.432	0.428	0.424
	l_4		0.424	0.420	0.415	0.420	0.424
	l_5		0.428	0.420	0.407	0.407	0.420
	l_6			0.428	0.398	0.398	0.407
	l_7				0.390	0.394	0.403
	l_8				0.390	0.390	0.398
	l_9				0.390	0.386	0.394
	l_{10}				0.390	0.386	0.390
	l_{11}				0.398	0.386	0.390
	l_{12}				0.407	0.386	0.390
	l_{13}					0.386	0.390
	l_{14}					0.386	0.390
	l_{15}					0.386	0.390
	l_{16}					0.386	
	l_{17}					0.386	
SPACING BETWEEN DIRECTORS (s_{ik}/λ)		0.20	0.20	0.25	0.20	0.20	0.308
DIRECTIVITY RELATIVE TO HALF-WAVE DIPOLE (dB)		7.1	9.2	10.2	12.25	13.4	14.2
DESIGN CURVE (SEE FIGURE 10.27)		(*A*)	(*B*)	(*B*)	(*C*)	(*B*)	(*D*)

(SOURCE: Peter P. Viezbicke, *Yagi Antenna Design*, NBS Technical Note 688, December 1976).

C. A. Balanis, *Antenna Theory: Analysis and Design*, 3rd ed., New York, NY, USA: Wiley-Interscience, 2005.

Today: building a VHF antenna (~145 MHz)

International Telecommunication Union (ITU)
[United Nations]

High frequency	HF	7	3–30 MHz 100–10 m	a (I s u
Very high frequency	VHF	8	30–300 MHz 10–1 m	F ra a ra a w e
Ultra high frequency	UHF	9	300– 3,000 MHz 100–10 cm	T ra b w G m p s (S
Super high frequency	SHF	10	3–30 GHz 10–1 cm	F D s b

IEEE standard

Radar-frequency bands according to IEEE standard[17]

Band designation	Frequency range	Explanation of meaning of letters
HF	0.003 to 0.03 GHz	High frequency[18]
VHF	0.03 to 0.3 GHz	Very high frequency[18]
UHF	0.3 to 1 GHz	Ultra-high frequency[18]
L	1 to 2 GHz	Long wave
S	2 to 4 GHz	Short wave
C	4 to 8 GHz	Compromise between S and X
X	8 to 12 GHz	Used in World War II for fire control, X for cross (as in crosshair). Exotic.[19]
K_u	12 to 18 GHz	*Kurz*-under
K	18 to 27 GHz	German: *Kurz* (short)
K_a	27 to 40 GHz	*Kurz*-above
V	40 to 75 GHz	
W	75 to 110 GHz	W follows V in the alphabet[20]
mm or G	110 to 300 GHz[note 1]	Millimeter[17]

https://en.wikipedia.org/wiki/Radio_spectrum

Wavelength?

- Frequency (f) and wavelength (λ) relate by the speed of light (c)
- c [m/s] = λ [m] * f [Hz, or 1/s]
- c is what value?
- Certain frequencies are publicly usable, some must be licensed for use, some are restricted
  - Why are frequencies allocated like this?
  - In the U.S., regulated by the Federal Communications Commission (FCC)
  - Restrictions are transmit only; anyone can listen to anything

The tape measure Yagi

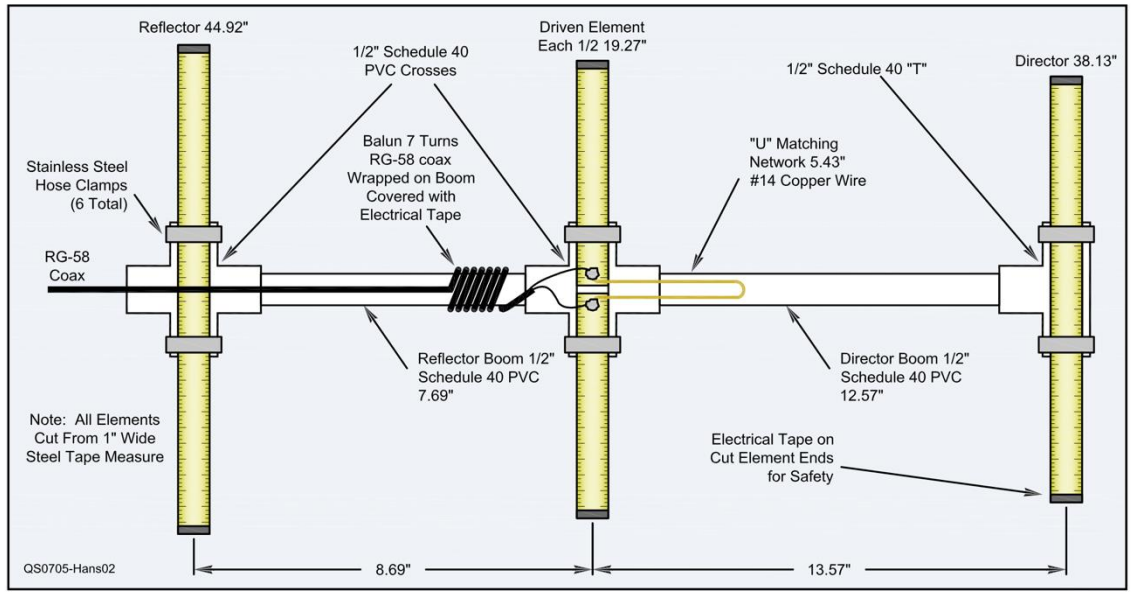


Figure 2 — 135 MHz tape measure beam assembly.

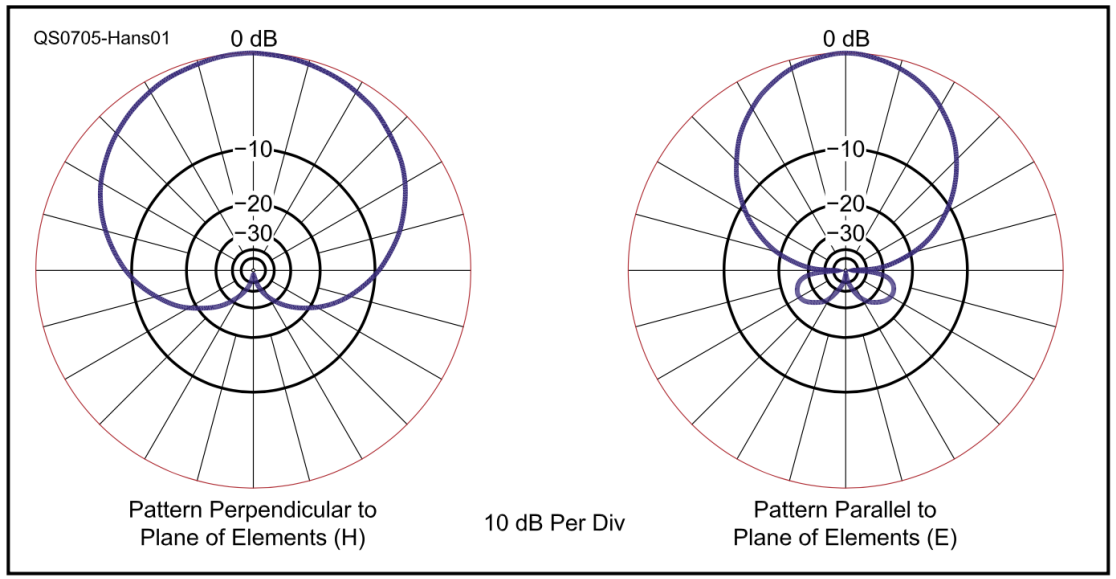
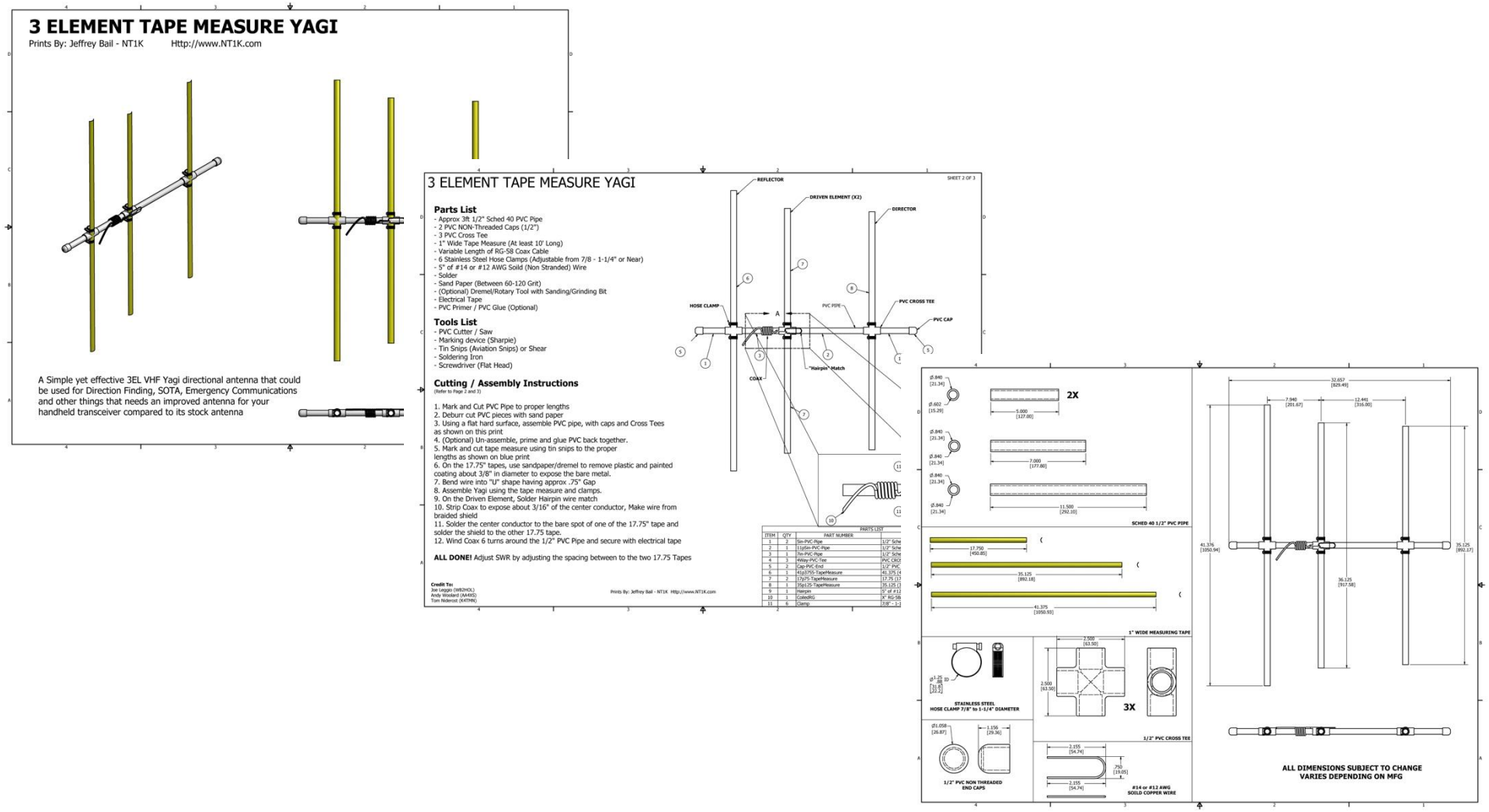


Figure 1 — YAGI-CAD predicted tape measure beam patterns.

J. T. Hanson, Adapting a Three Element Tape Measure Beam for Power Line Noise Hunting, QST Magazine, May 2007.

2007 design (and more) summarized by NT1K



https://nt1k.com/vhf-3el-tape-measure-yagi/

Our design: Dr. Johnston (Villanova ECE)

- Overall plans credited to Joe Leggio (WB2HOL) Andy Woolard (AA4XS) Tom Niderost (K4TMN) with prints by Jeffrey Bail
- Plans designed and modified by Dr. Alan Johnston here at VU
- Components already cut to size (but watch out for sharp edges!)
- Plans sent out ahead of time

Connect to "RTL-SDR"

REALTEK

- Realtek designed and sells the RTL2832U chip
  - "The RTL2832U is a high-performance DVB-T COFDM demodulator that supports a USB 2.0 interface. The RTL2832U is compatible with NorDig Unified 1.0.3, D-Book 5.0, and EN300 744 (ETSI Specification)."
  - https://www.realtek.com/Product/Index?id=615
- It's a digital TV signal receiver
- In 2010, hackers discovered it can be configured to stream raw received data over its USB interface
- Now a super cheap ($20) flexible radio receiver (typically 24 MHz to 1766 MHz, depending on product)

The 2 m band

- ARRL maintains a "band plan"
- Ham Radio groups generally divide 2 m band into 15 kHz or 20 kHz channels
  - PA, NJ are 15 kHz
- With 4 MHz bandwidth, that's 266 channels!

2 Meters (144-148 MHz)

144.00-144.05	EME (CW)
144.05-144.10	General CW and weak signals
144.10-144.20	EME and weak-signal SSB
144.200	National calling frequency
144.200-144.275	General SSB operation
144.275-144.300	Propagation beacons
144.30-144.50	New OSCAR subband
144.50-144.60	Linear translator inputs
144.60-144.90	FM repeater inputs
144.90-145.10	Weak signal and FM simplex (145.01,03,05,07,09 are widely used for packet)
145.10-145.20	Linear translator outputs
145.20-145.50	FM repeater outputs
145.50-145.80	Miscellaneous and experimental modes
145.80-146.00	OSCAR subband
146.01-146.37	Repeater inputs
146.40-146.58	Simplex
146.52	National Simplex Calling Frequency
146.61-146.97	Repeater outputs
147.00-147.39	Repeater outputs
147.42-147.57	Simplex
147.60-147.99	Repeater inputs

Notes: The frequency 146.40 MHz is used in some areas as a repeater input. This band plan has been proposed by the ARRL VHF-UHF Advisory Committee.

https://www.arrl.org/band-plan

Frequencies to look for

- Our safari transmitters:
  - 144.090 MHz, 146.580 MHz, 147.540 MHz
  - Morse code message for ~30 s, off for 2 minutes, repeat
  - Part II: compete to collect tokens from all three the fastest!
- FM radio stations
- JSON file will give SDR++ a lot of interesting pre-sets
  - Airport, weather, popular ham bands…
- Check heavens-above.com "Amateur Radio Satellites" (+ISS?)
- Repeaterbook.com repeaters within 10 miles. All +0.6 MHz offset
  - 147.1800 MHz W2MMD Pitman NJ
    147.1200 MHz KC2DUX Woodbury NJ (maybe offline?)
    145.3900 MHz K2DX Monroe Township NJ
    146.8650 MHz K2UK Pine Hill NJ

https://www.arrl.org/band-plan

Part I tasks

- Team up
- Gather materials needed for antenna and assemble
  - See documents sent out ahead of time
- Install SDR++ on your laptops using instructions at

`https://github.com/alanbjohnston/CubeSatSim/wiki/sdrpp-setup-for-windows`

  - Use `frequency_manager_config.json` to get station presets
- Test SDR++ with a USB software defined radio (SDR)
  - RTL-SDRs are checked out to individuals
- Test antenna with a USB SDR and/or NanoVNA

SIGNAL SAFARI: PART II

Looking for signals!

- Go outside, find a relatively unobstructed spot, point toward PHL
  - Signal will improve dramatically with a little more elevation above ground
- Our safari transmitters:
  - 144.090 MHz, 146.580 MHz, 147.540 MHz
  - Morse code message for ~30 s, off for 2 minutes, repeat
- Compete to collect tokens from all three the fastest!
  - Sticker, wire, candy
- Check heavens-above.com for "Amateur Radio Satellites" (+ISS?)
- Repeaterbook.com repeaters <10 miles. +0.6 MHz offset

147.1800	MHz	W2MMD	Pitman NJ
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