

Building and Testing the W6NBC Double Delta Slot HF Antenna

by Mark Smith

BayCon 2021, February 6



Who am I?

- Mark Smith, aka Smitty or SmittyHalibut
- Callsign, bad timing:
 - I'm **KR6ZY** as I write this.
 - I hope to be **N6MTS** by the time you see this.
- SmittyHalibut on Twitter and YouTube

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What is this antenna?

- John Portune, W6NBC
 - Many articles in many publications, such as QST
 - Interested in Slot antennas
-
- Presented an HF Slot Antenna at QSO Today Ham Expo 2020
<https://w6nbc.com/articles/2020-TBDdoubleDelta.pdf>

Why this antenna?

- Small footprint like a vertical half wave (no ground plane)
- Radiates like a horizontal dipole at the elevation of the top of the antenna
- Multi-band (requires remote tuner)
- Electrically pointable, no rotator.



Why this antenna?

- Small footprint like a vertical half wave (no ground plane)
- Radiates like a horizontal dipole at the elevation of the top of the antenna
- Multi-band (requires remote tuner)
- Electrically pointable, no rotator.
- **Sounds great, right?**

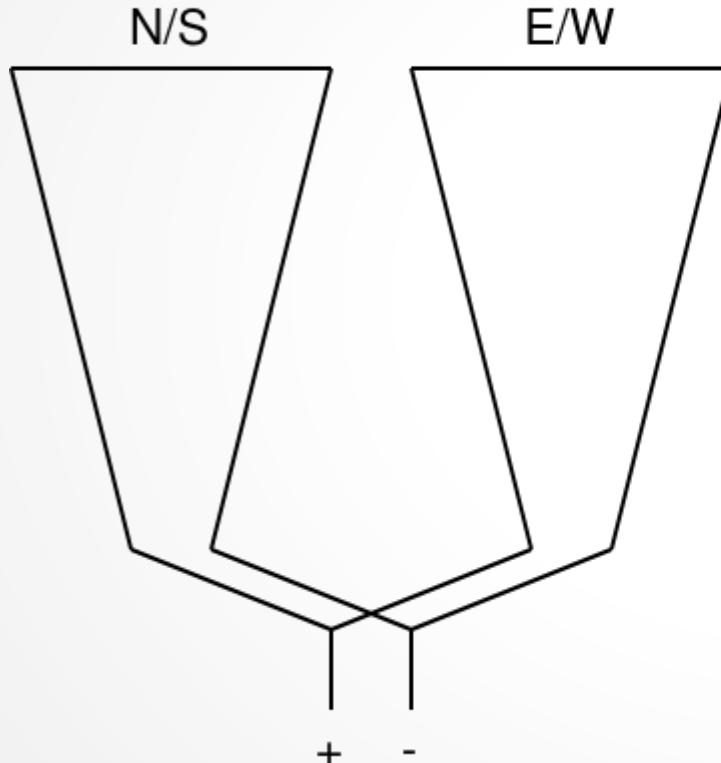


Goals: I blame George

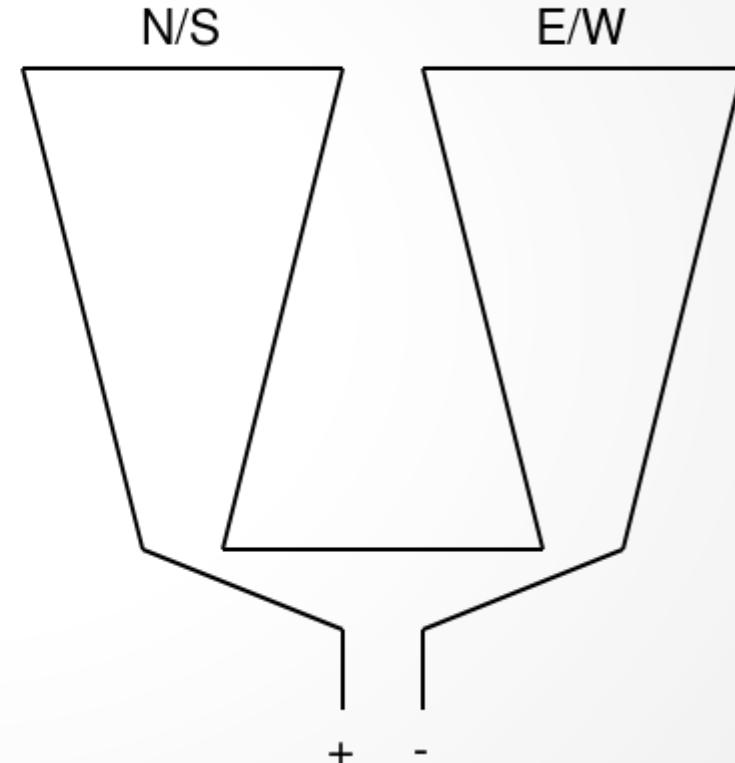
- Build options:
 - Two loops in Parallel
 - Two loops in Series

Parallel or Series?

Parallel



Series

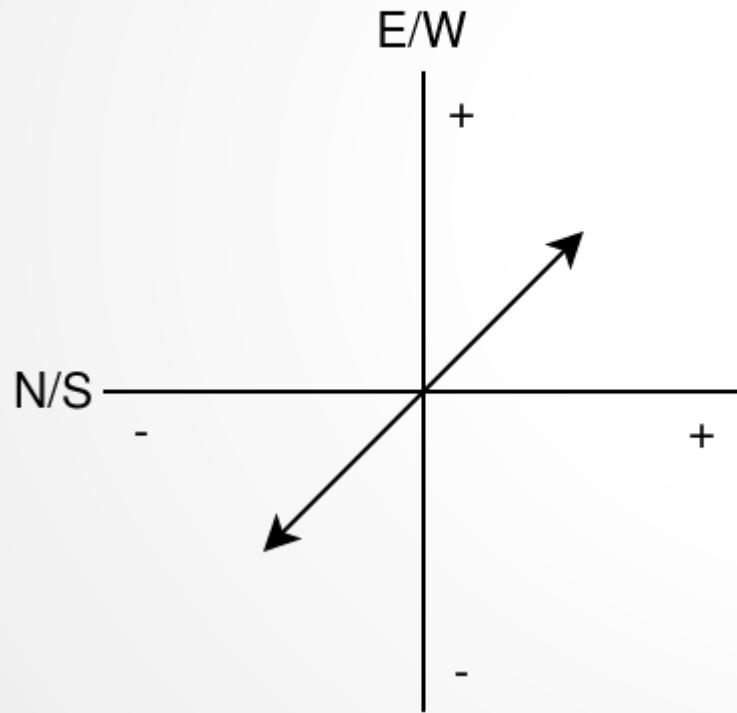


Goals: I blame George

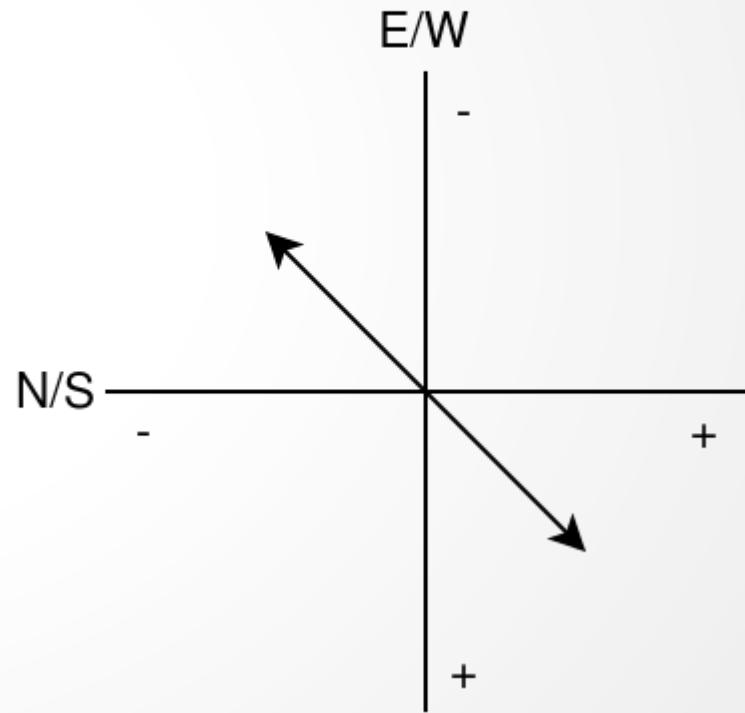
- Build options:
 - Two loops in Parallel
 - Two loops in Series
- Rotation options:
 - 90 degrees: Reverse phase of one loop, consistent impedance
 - 45 degrees: Two loops, or single loop, different impedances.

Dual loops, 90 degree rotation

Two loops, in phase:
North East, and South West

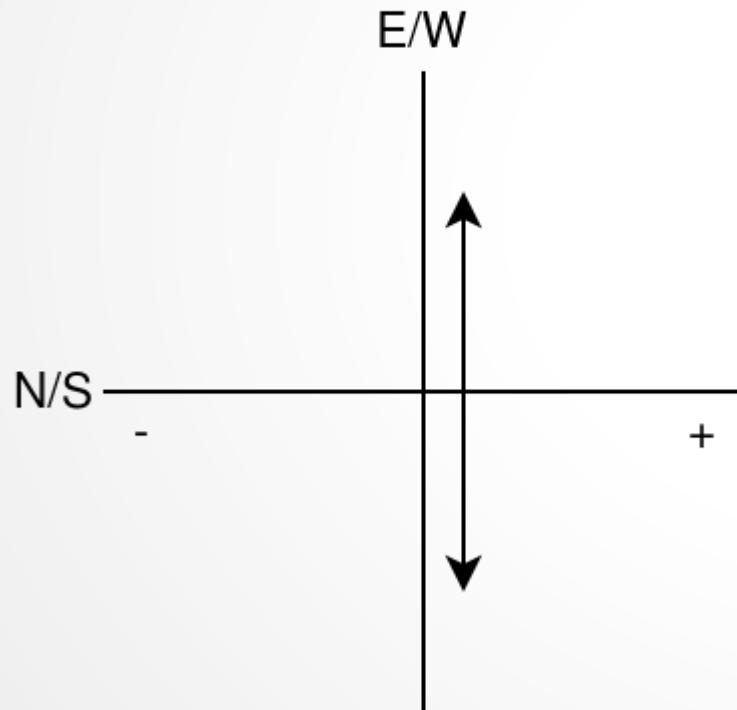


Two loops, reverse phase:
North West, and South East

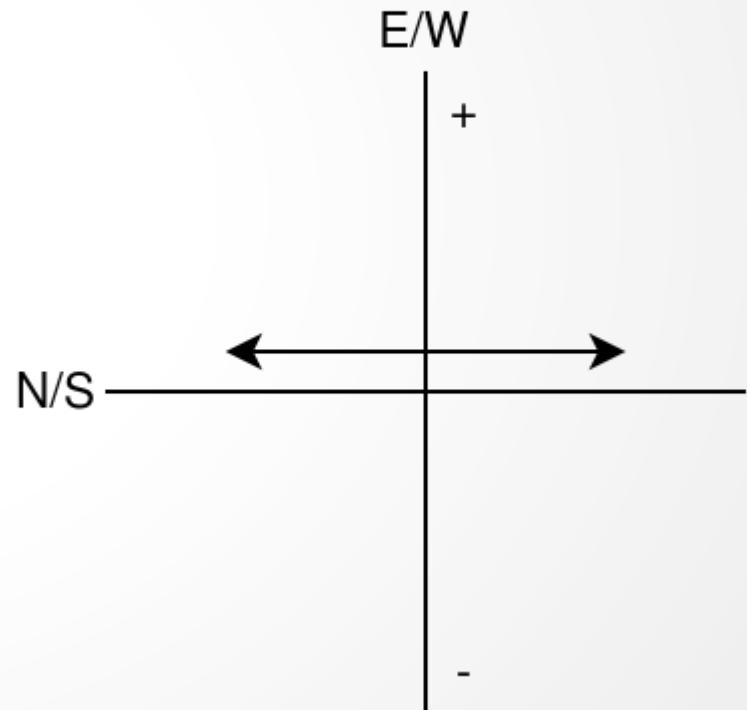


Single loop, fill in the 45 degrees

Single N/S loop:
North, and South



Single E/W loop:
East, and West



Goals: I blame George

- Is one of these options better than the other?

Goals: I blame George

- Is one of these options better than the other?
- Can we build the antenna to use any/all of those options?

Goals: I blame George

- Is one of these options better than the other?
- Can we build the antenna to use any/all of those options?
- Is it worth the added complexity?

What are we talking about today?

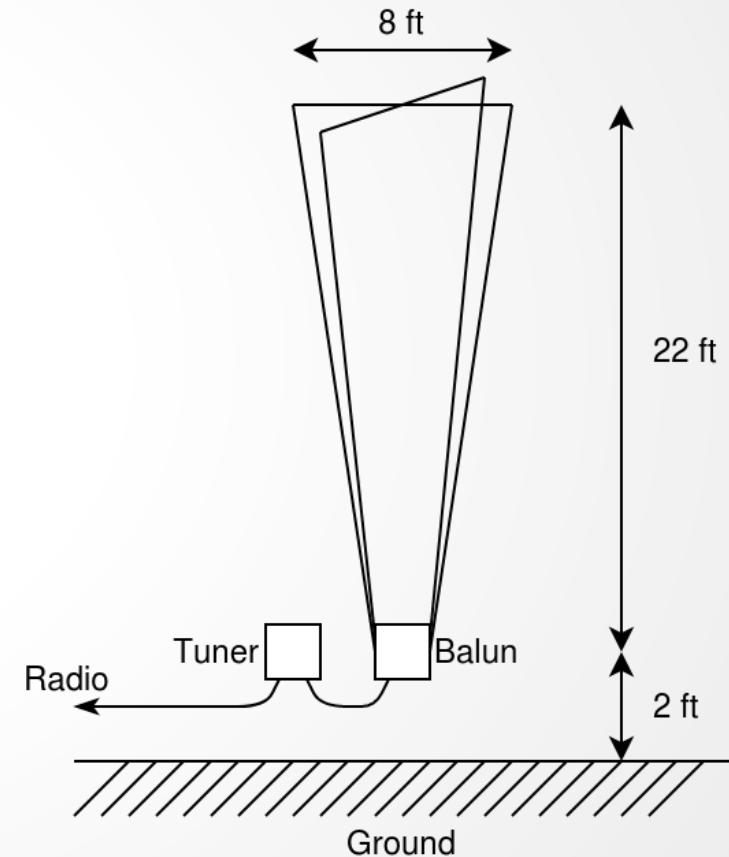
- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What are we talking about today?

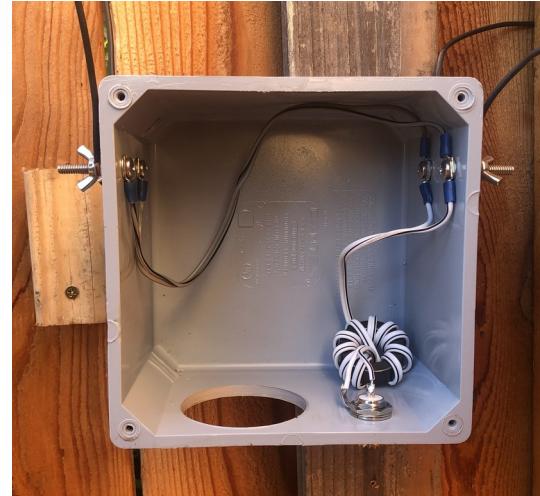
- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

Let's build it!

- Mast: 24ft 2x4 lumber (metal is fine)
- Base is 2ft off the ground
- Spreader: 4ft (from mast) fiberglass, 8ft total width at top.
- 1:1 Balun: 11 turns on FT140-43 toroid
- Tuner: LDG RT-600 remote tuner
- Feedline: 200ft of RG-213
(replacing with DXE 400MAX)

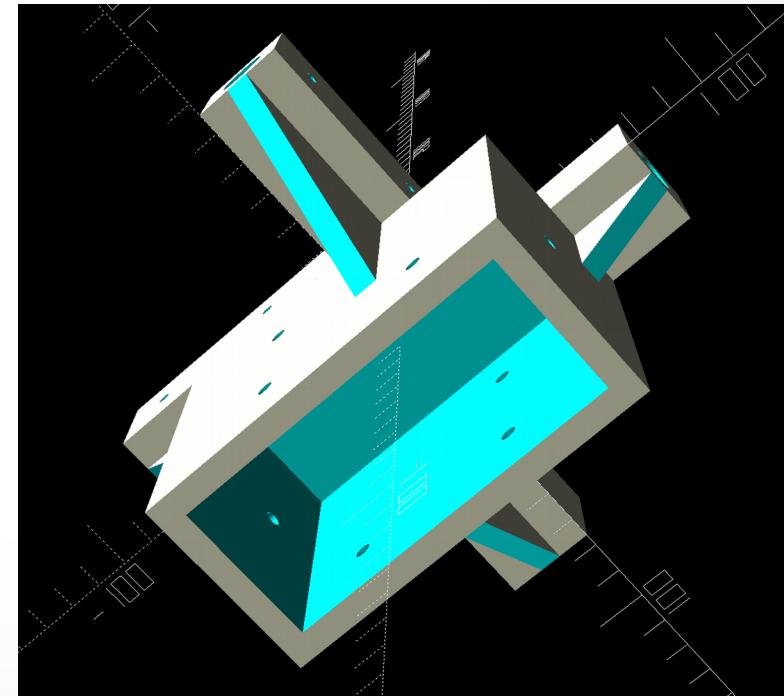
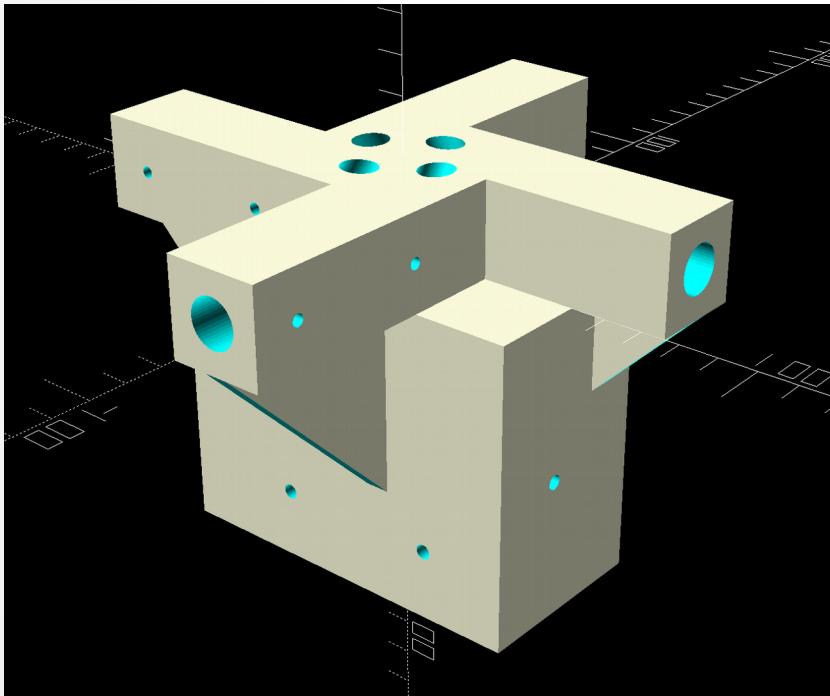


Let's build it!



Let's build it!

- Spreader bracket model is parametric OpenSCAD, 3D printed.



Let's build – Oops...

- W6NBC's design is:
Radio → Feedline → **Balun** → **Tuner** → Antenna
- What I built is:
Radio → Feedline → **Tuner** → **Balun** → Antenna

Let's build – Oops...

- W6NBC's design is:
Radio → Feedline → **Balun** → **Tuner** → Antenna
Unbalanced tuner, in balanced circuit
- What I built is:
Radio → Feedline → **Tuner** → **Balun** → Antenna
Balun designed for $50+j0$ ohms, used in wildly complex impedance circuit

Let's build – Oops...

- W6NBC's design is:
Radio → Feedline → **Balun** → **Tuner** → Antenna
Unbalanced tuner, in balanced circuit
- What I built is:
Radio → Feedline → **Tuner** → **Balun** → Antenna
Balun designed for $50+j0$ ohms, used in wildly complex impedance circuit
- Neither are great.
- I'm proceeding with my design .. because ..

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

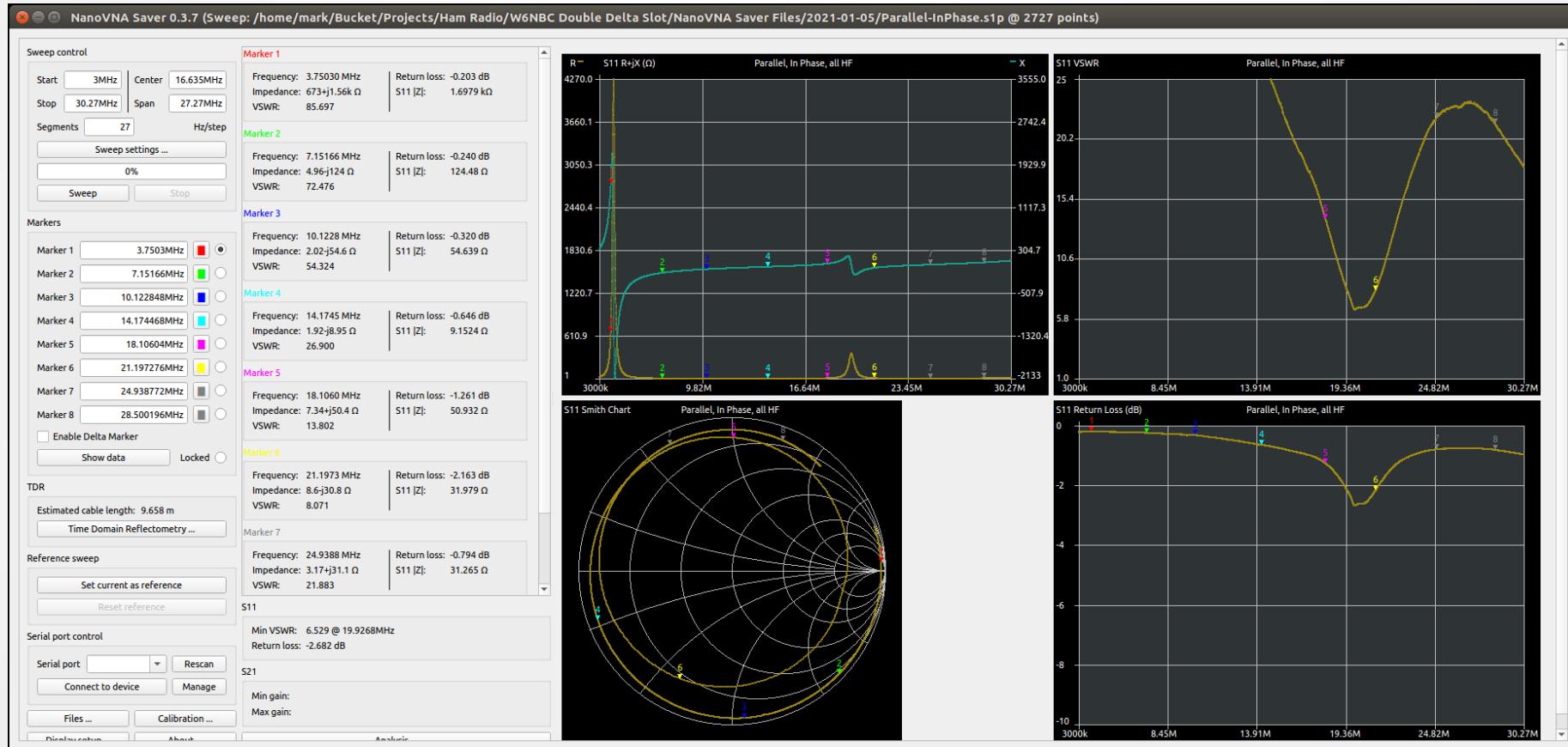
Let's measure it!

- I used a NanoVNA-F
 - Hopefully you saw Alan Wolke W2AEW's presentation on the NanoVNA
 - Adventures in NanoVNA calibration!

Let's measure it!

- I used a NanoVNA-F
 - Hopefully you saw Alan Wolke W2AEW's presentation on the NanoVNA
 - Adventures in NanoVNA calibration!
- NanoVNA Saver software
 - 3.0MHz to 30.27MHz in 2727 steps of 10kHz each.
 - Measured S11 parameters.
 - Saves data in standard „Touchstone“ file format: .s1p files
 - Does lots of visualizations of the data too, but I'm interested in the .s1p files.

Let's measure it!



What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

How do we analize this?

- What does the antenna look like natively?

How do we analize this?

- What does the antenna look like natively?
- What is the theoretical perfect matching network?

How do we analize this?

- What does the antenna look like natively?
- What is the theoretical perfect matching network?
- What matching network can the RT-600 *actually* make?
 - 0 to 1270pF in 10pF steps
 - 0 to 12700nH in 100nH steps

How do we analize this?

- What does the antenna look like natively?
- What is the theoretical perfect matching network?
- What matching network can the RT-600 *actually* make?
 - 0 to 1270pF in 10pF steps
 - 0 to 12700nH in 100nH steps
- What impedance is presented to the radio given the *actual* matching network?

How do we analize this?

- I wrote a Python script that performs all these calculations

```
[x] [15:37:46] mark@crossthread: ~/Bucket/Projects/Ham Radio/W6NBC Double Delta Slot/NanoVNA Saver Files/2021-01-05$ ./make_matching_network.py
[15:37:46] mark@crossthread: ~/Bucket/Projects/Ham Radio/W6NBC Double Delta Slot/NanoVNA Saver Files/2021-01-05$ ./make_matching_network.py
matplotlib not found while setting up plotting
# File: Parallel-InPhase.slp
### Band: 80m Complete
-----Measurements:----- -----Ideal Network:----- -----Tuner Network:----- -----Tuner Impedance:-----
--Freq--- --R:--- --X:--- --|Z|--- -SWR- --C:--- --L:--- --C:--- --C:--- --L:--- --C:--- --R:--- --X:--- --|Z|--- -SWR-
3.50MHz 137.98 +748.16j 760.8 15.22 20700nH 157pF 12700nH 160pF !11 47.57 -164.87j 171.6 3.43
3.62MHz 257.78 +1013.08j 1045.4 20.91 20094nH 136pF 12700nH 140pF !11 45.62 -148.13j 155.0 3.10
3.75MHz 673.29 +1558.69j 1697.9 33.96 19522nH 114pF 12700nH 110pF !11 54.80 -182.06j 190.1 3.80
3.88MHz 2521.36 +2134.71j 3303.7 66.07 18997nH 96pF 12700nH 100pF !11 45.59 -132.68j 140.3 2.81
4.00MHz 2805.51 -2021.92j 3458.2 69.16 18261nH 79pF 12700nH 80pF !11 48.81 -134.34j 142.9 2.86
### Band: 80m CW only
-----Measurements:----- -----Ideal Network:----- -----Tuner Network:----- -----Tuner Impedance:-----
--Freq--- --R:--- --X:--- --|Z|--- -SWR- --C:--- --L:--- --C:--- --C:--- --L:--- --C:--- --R:--- --X:--- --|Z|--- -SWR-
3.50MHz 137.98 +748.16j 760.8 15.22 20700nH 157pF 12700nH 160pF !11 47.57 -164.87j 171.6 3.43
3.56MHz 184.17 +864.21j 883.6 17.67 20447nH 146pF 12700nH 150pF !11 46.06 -155.20j 161.9 3.24
3.62MHz 257.78 +1013.08j 1045.4 20.91 20094nH 136pF 12700nH 140pF !11 45.62 -148.13j 155.0 3.10
3.69MHz 411.90 +1258.98j 1324.6 26.49 19802nH 124pF 12700nH 120pF !11 54.46 -184.33j 192.2 3.84
3.75MHz 673.29 +1558.69j 1697.9 33.96 19522nH 114pF 12700nH 110pF !11 54.80 -182.06j 190.1 3.80
### Band: 75m SSB only
-----Measurements:----- -----Ideal Network:----- -----Tuner Network:----- -----Tuner Impedance:-----
--Freq--- --R:--- --X:--- --|Z|--- -SWR- --C:--- --L:--- --C:--- --C:--- --L:--- --C:--- --R:--- --X:--- --|Z|--- -SWR-
3.75MHz 673.29 +1558.69j 1697.9 33.96 19522nH 114pF 12700nH 110pF !11 54.80 -182.06j 190.1 3.80
3.81MHz 1216.70 +1943.78j 2293.2 45.86 19294nH 105pF 12700nH 100pF !11 55.65 -183.05j 191.3 3.83
3.88MHz 2521.36 +2134.71j 3303.7 66.07 18997nH 96pF 12700nH 100pF !11 45.59 -132.68j 140.3 2.81
3.94MHz 4269.74 -28.54j 4269.8 85.40 18567nH 87pF 12700nH 90pF !11 46.66 -129.70j 137.8 2.76
4.00MHz 2805.51 -2021.92j 3458.2 69.16 18261nH 79pF 12700nH 80pF !11 48.81 -134.34j 142.9 2.86
### Band: 60m
-----Measurements:----- -----Ideal Network:----- -----Tuner Network:----- -----Tuner Impedance:-----
--Freq--- --R:--- --X:--- --|Z|--- -SWR- --C:--- --L:--- --C:--- --C:--- --L:--- --C:--- --R:--- --X:--- --|Z|--- -SWR-
```

How do we analize this?

- Too much data, I won't present it all here. Go to my github:

<https://github.com/SmittyHalibut/DoubleDeltaSlotAntenna>

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

But first! A DISCLAIMER

- All of this is based on my particular build of this antenna.

But first! A DISCLAIMER

- All of this is based on my particular build of this antenna.
- The antenna design is very flexible, thanks to the tuner.

But first! A DISCLAIMER

- All of this is based on my particular build of this antenna.
- The antenna design is very flexible, thanks to the tuner.
- If you build yours with different dimentions, your numbers
will be different.

But first! A DISCLAIMER

- All of this is based on my particular build of this antenna.
- The antenna design is very flexible, thanks to the tuner.
- If you build yours with different dimentions, your numbers ***will be different.***
- That's why all my tools are freely available on GitHub, so you can similarly analize your own antenna if you want.

Actual Impedance, With Tuner

Band	Parallel	Series	Single	Notes
80m	SWR!	SWR!	SWR!	None are good, 3:1 to 4:1. L is out of range.
75m	SWR!	Hi X	SWR!	L is out of range. Series SWR is low, but <i>very</i> reactive.
60m	Great	Good	Great	Series is ok, but reactive. C is out of range
40m	Good	Hi X	Good	All could use more C, but close. Series is 2.2:1
30m	Hi X	Great	SWR!	Parallel and Single need more C, very reactive
20m	Hi X	Hi X	SWR!	Very low R, high X, hard to match. Varies over band.
17m	Great	Hi X	Great	Series is still better than 2:1, just reactive.
15m	Good	Good	Good	All good, not great. Better than 2:1, a bit reactive.
12m	Great	Good	Good	All better than 2:1, a bit reactive.
10m	Good	Good	Good	All good, not great. Better than 2:1, a bit reactive.

What does this all mean?

- Parallel:
 - Good or Great from 60m to 10m, except 30m and 20m

What does this all mean?

- Parallel:
 - Good or Great from 60m to 10m, except 30m and 20m
- Series:
 - Good (not Great) on 60m, and 15m up.
 - Great on 30m! Usable but reactive on 40m, 20m, and 17m.

What does this all mean?

- Parallel:
 - Good or Great from 60m to 10m, except 30m and 20m
- Series:
 - Good (not Great) on 60m, and 15m up.
 - Great on 30m! Usable but reactive on 40m, 20m, and 17m.
- Single:
 - Good or Great from 60m to 10m, except...
 - Unusably high SWR on 30m and 20m

What does this all mean?

- Parallel:
 - Good or Great from 60m to 10m, except 30m and 20m
- Series:
 - Good (not Great) on 60m, and 15m up.
 - Great on 30m! Usable but reactive on 40m, 20m, and 17m.
- Single:
 - Good or Great from 60m to 10m, except...
 - Unusably high SWR on 30m and 20m
- Minimal on-air testing matches this.

What's it good at?

- It has all the benefits John mentions in his presentation and article.

What's it good at?

- It has all the benefits John mentions in his presentation and article.
- Coveres all bands from 60m to 10m to varying degrees.
 - Might also work on 6m, I didn't measure.

What's it good at?

- It has all the benefits John mentions in his presentation and article.
- Coveres all bands from 60m to 10m to varying degrees.
 - Might also work on 6m, I didn't measure.
- It's easy to construct, could be made „field-day“ portable.
 - Probably not SOTA portable.

What's it not so good at?

- 80m and lower are a complete loss.
 - A taller/larger loop would fix this.

What's it not so good at?

- 80m and lower are a complete loss.
 - A taller/larger loop would fix this.
- 20m is not great in any configuration. It's usable, but reactive.

Is it worth the complexity for Parallel and Series?

- If I cared strongly about 30m, I might build a switching network to change between Parallel and Series configuration.
- I'm willing to trade 30m for a simpler build, so I will keep mine in Parallel.

Is it worth the complexity for Parallel and Series?

- If I cared strongly about 30m, I might build a switching network to change between Parallel and Series configuration.
- I'm willing to trade 30m for a simpler build, so I will keep mine in Parallel.
- Someone with different goals, or an antenna with different numbers, could easily justify the complexity.

Is it worth supporting Single loops for 45 deg?

- Would it help?
 - The modeled beam width of the antenna is 90deg at -3db, so rotating 45deg would only get you 3db.
 - The side nulls are narrower, so it might be worth it for pointing nulls.

Is it worth supporting Single loops for 45 deg?

- Would it help?
 - The modeled beam width of the antenna is 90deg at -3db, so rotating 45deg would only get you 3db.
 - The side nulls are narrower, so it might be worth it for pointing nulls.
- Can it be done?
 - Single is very similar to Parallel: Good from 60m to 10m, except 30m and 20m

Is it worth supporting Single loops for 45 deg?

- *Should* it be done?
 - The RT-600 remembers the matching network for a given frequency.
 - Changing the antenna from Parallel/Series to Single changes its impedance, causing the tuner to have to re-tune every time, losing the benefit of remembering the matching network for that frequency.
 - The tuner is more of a pain than I expected; anything that makes it even less convenient is not good.

Is it worth supporting Single loops for 45 deg?

- *Should* it be done?
 - The RT-600 remembers the matching network for a given frequency.
 - Changing the antenna from Parallel/Series to Single changes its impedance, causing the tuner to have to re-tune every time, losing the benefit of remembering the matching network for that frequency.
 - The tuner is more of a pain than I expected; anything that makes it even less convenient is not good.
- So, No. I don't think it's worth bothering with Single loops.

Summary, For My Antenna

- Dual loops, in Parallel.

Summary, For My Antenna

- Dual loops, in Parallel.
- Remote switch the phase of one loop, for 90 deg rotation.

Summary, For My Antenna

- Dual loops, in Parallel.
- Remote switch the phase of one loop, for 90 deg rotation.
- No support for Series, or Single loops.

Summary, For My Antenna

- Dual loops, in Parallel.
- Remote switch the phase of one loop, for 90 deg rotation.
- No support for Series, or Single loops.
- Covers 60m to 10m, but 30m and 20m require additional tuning in the shack.

Summary, For My Antenna

- Dual loops, in Parallel.
- Remote switch the phase of one loop, for 90 deg rotation.
- No support for Series, or Single loops.
- Covers 60m to 10m, but 30m and 20m require additional tuning in the shack.
- I will probably make a second one for my club (CQ805) for portable use, like Field Day.

What are we talking about today?

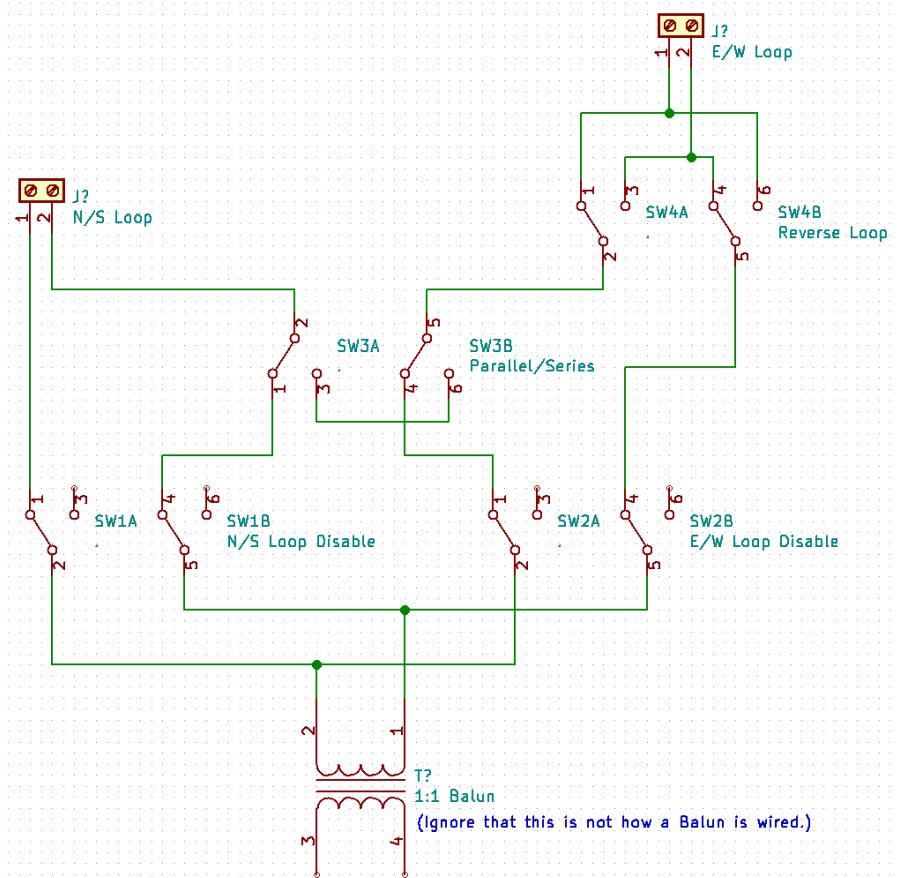
- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What are we talking about today?

- Background and Goals
- Antenna Build
- Measurements
- Analysis
- Conclusions
- What's next?

What if I want all the options!?

- Switching Network:
 - SW1, SW2 disable each loop.
(normally enabled)
 - SW3 configures for Series
(normally Parallel)
 - SW4 reverses polarity of E/W loop.
- Run power for SW1/2 through SW3 (third pole) for safety interlock.



What if I want all the options!?

- Could design a board:
 - SO-239 input, spot for 1:1 balun, relays, terminals for loops.
 - Microcontroller to control the relays.
 - Using George's serial protocol for remote control over RS-485 or ZigBee

More work from W6NBC soon

- John Portune is continuing development of this antenna.
- I won't steal his thunder here, but it's pretty cool.

- Watch his presentation in the QSO Today Expo, March 2021

Notes, and Q&A

- Me: @SmittyHalibut on Twitter and YouTube
- John's article on the Double Delta Slot HF Antenna:
<https://w6nbc.com/articles/2020-TBDdoubledelta.pdf>
- My data and analysis:
<https://github.com/SmittyHalibut/DoubleDeltaSlotAntenna>