Modeling an 80/40/20M Fan Dipole for DX

New Station – New Antennas!
  • Installation and SWR Response
  • Where is the DX?
  • How do these Dipoles “Play?” (EZNEC)

What about Terrain?
  • HFTA and Terrain
  • The effect on these Dipoles

Potential Improvements
  • Higher Dipoles?
  • Different Types of Antennas?

Appendix
  Effect of Sea Water
  Other HF Bands

Larry Banks, W1DYJ
First licensed: 1962 as KN1VFX (Novice)
W1DYJ since 1966 – Amateur Extra
10 Matthews Way    Harpswell    ME
33 Blueberry Hill Road    Woburn    MA
New Station ~ New Antennas!

- Bought a 2nd home in Harpswell, ME, in 2008
- Need HF antennas on 80/40/20 to understand local conditions
- No tall trees -- did not want a tower
- Low band verticals make sense – but radials are a lot of work

→ Simple Dipoles for now: 80, 40, 20 in a “Fan”
  - Use a corner of the house as the center point
    - (Yes – too low!)
  - Build Them – Understand Them – Improve Them
- Add 160, 60, 30, 17, 12, 10, 6 in the future
Modeling an 80/40/20M Fan Dipole for DX

Simple Dipoles for now: 80, 40, 20 Fan

Use a corner of the house as the center point

(The numbers on the wires are for use with EZNEC.)
Antenna Orientation

Brunswick, ME
10 Matthews Way

Modeling an 80/40/20M Fan Dipole for DX

Japan
335°

Europe
60°

Africa
90°

South America
170°

Modeling an 80/40/20M Fan Dipole for DX
March 2012
Actual Installation

Cables through the wall in Shack

Polyphaser Lightening Protection

VHF / UHF

Screw Eye for 80M

Balun and Dipole Center

Dipole Center
Actual installation

- **Dipole Center**
  - 80M
  - 40M
  - 20M

- **Screw Eye for 80M**
- **VHF / UHF**
  - 40M
  - 20M

- **Pulleys**
  - 40M
  - 20M
Modeling an 80/40/20M Fan Dipole for DX

The SWR is measured at the transceiver. The attenuation of the 30 ft. of RG-8X coax feeding the antenna can account for most of the difference between measured and theoretical SWR.
Where is the DX?

At what angle (from the horizon) does the RF arrive?

We must always remember this simple truth:
The ionosphere controls the elevation angles of the RF we see at our location, not our antenna!

Data from the ARRL Antenna Book, Dean Straw N6BV editor.

Information available as tables: the statistical distribution of elevation angles that are necessary for communication via the ionosphere from one location to another.

Also part of the software program HFTA (High Frequency Terrain Analysis)
Primer on HFTA’s “Elevation-Statistics” Models

The angle the RF arrives from.

Frequency

Freq. = 3.6 MHz
Max. Gain = 20 ft
Dipole Fig. of Merit = -22.8

Geographic Information:
W1-MA <-> Europe
(There are MANY files.)

The percentage of time the RF is at this arrival angle.

HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03
Primer on HFTA’s “Elevation-Statistics” Models

Note: The statistical data is an overall average of all time; i.e. for any time, any day, any season, any part of the 11-year sunspot cycle.

Specific propagation “today” will be very limited in angle.

Example: About 8.5% of the time, European 80M RF arrives at an arrival angle of 13°.

Conclusion, from this one graph: About 80% of the time, European 80M RF arrives at arrival angles between 5° → 22°.
Elevation Statistics for New England – 80M

Europe

5-22°

Africa

3-4°

Japan

4-11°

S. America

5-20°

GOAL
Elevation Statistics for New England – 40M

Europe
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 6-16°

Africa
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 3-11°

Japan
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 5-11°

S. America
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 4-20°

Elevation Statistics for New England – 40M

Europe
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 6-16°

Africa
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 3-11°

Japan
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 5-11°

S. America
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 4-20°

Elevation Statistics for New England – 40M

Europe
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 6-16°

Africa
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 3-11°

Japan
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 5-11°

S. America
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 4-20°

Elevation Statistics for New England – 40M

Europe
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 6-16°

Africa
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 3-11°

Japan
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 5-11°

S. America
- Gain, dBi
- Takeoff Angle, Degrees
- Elevation Statistics, %
- 4-20°
Elevation Statistics for New England – 20M

Europe

Africa

Japan

S. America

GOAL

3-18°

3-15°
Modeling an 80/40/20M Fan Dipole for DX

The previous slides show where the DX comes from, so...

How do these dipoles “play” from 3-22°

using EZNEC:

**EZNEC** is a powerful but easy-to-use program for modeling and analyzing nearly any kind of antenna *in its actual operating environment*.

**EZNEC:**

- plots azimuth and elevation patterns
- tells you gain, feedpoint impedance, SWR, and current distribution
- reports beamwidth, 3-dB pattern points, f/b ratio, takeoff angle
- …and more.
REVIEW ~ Ideal EZNEC Dipole Patterns

Free Space

1/2 λ above real ground

1/4 λ above real ground
80M EZNEC patterns

Data shown for 3.666 MHz.
Height = ~1/14 \( \lambda \)

<table>
<thead>
<tr>
<th>Elevation °</th>
<th>Gain (dBi) @ 60°</th>
<th>Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>3.9 dBi</td>
<td>△</td>
</tr>
<tr>
<td>20</td>
<td>-5.6</td>
<td>-9.5 dBi</td>
</tr>
<tr>
<td>10</td>
<td>-8.9</td>
<td>-12.8</td>
</tr>
<tr>
<td>5</td>
<td>-12.8</td>
<td>-16.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Azimuth °</th>
<th>Gain (dBi) @ 20°</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 (Europe)</td>
<td>-5.6 dBi</td>
<td>-4.7</td>
</tr>
<tr>
<td>90 (Africa)</td>
<td>-4.7</td>
<td>-4.9 ± 0.9dB</td>
</tr>
<tr>
<td>170 (S. America)</td>
<td>-5.8</td>
<td></td>
</tr>
<tr>
<td>335 (Japan)</td>
<td>-4.0</td>
<td></td>
</tr>
</tbody>
</table>
40M EZNEC patterns
Data shown for 7.044 MHz.
Height = ~1/7 λ

<table>
<thead>
<tr>
<th>Elevation °</th>
<th>Gain (dBi) @ 60°</th>
<th>Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>4.8 dBi</td>
<td>△</td>
</tr>
<tr>
<td>20</td>
<td>-1.6</td>
<td>6.4 dB</td>
</tr>
<tr>
<td>10</td>
<td>-5.0</td>
<td>9.8</td>
</tr>
<tr>
<td>5</td>
<td>-9.1</td>
<td>-13.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Azimuth °</th>
<th>Gain (dBi) @ 20°</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 (Europe)</td>
<td>-1.6 dB</td>
<td>-2.1 ± 1.6 dB</td>
</tr>
<tr>
<td>90 (Africa)</td>
<td>-2.4</td>
<td></td>
</tr>
<tr>
<td>170 (S. America)</td>
<td>-0.8</td>
<td></td>
</tr>
<tr>
<td>335 (Japan)</td>
<td>-3.6</td>
<td></td>
</tr>
</tbody>
</table>
20M EZNEC patterns

Data shown for 14.15 MHz.

Height = ~ 0.27 λ

<table>
<thead>
<tr>
<th>Elevation °</th>
<th>Gain (dBi) @ 60°</th>
<th>Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>6.0 dBi</td>
<td>△</td>
</tr>
<tr>
<td>20</td>
<td>1.3</td>
<td>- 4.7 dB</td>
</tr>
<tr>
<td>10</td>
<td>- 1.8</td>
<td>- 7.8</td>
</tr>
<tr>
<td>5</td>
<td>- 5.9</td>
<td>-11.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Azimuth °</th>
<th>Gain (dBi) @ 20°</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 (Europe)</td>
<td>1.3 dBi</td>
<td>0.4 ± 0.9 dB</td>
</tr>
<tr>
<td>90 (Africa)</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>170 (S. America)</td>
<td>-0.5</td>
<td></td>
</tr>
<tr>
<td>335 (Japan)</td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>
Modeling an 80/40/20M Fan Dipole for DX

Conclusions

- We want our DX antennas to “play” from $3^\circ$ to $22^\circ$ and be omnidirectional

- These dipoles are “OK” for Azimuth $\pm \sim 1\frac{1}{2}$ dB
  - In this case low is good!

- These dipoles are not so good for Elevation
  - Gain straight up at $90^\circ$: 4 – 6 dBi
  - Gain where we want it, $<20^\circ$ is not so good: -5 to -17 dB

What about the effect of local terrain? $\rightarrow$ Next
The Effect of Terrain

HFTA (High Frequency Terrain Analysis)

• We have looked at where the Qs come from… (3-22°)
• We know these antennas aren’t great for DX… (-5 → -17 dB)
• But how does the local terrain in Harpswell, ME, effect the RF?

Remember this simple truth:
The ionosphere controls the elevation angles, not our transmitting antenna – *but the local terrain affects it!*
HFTA (HF Terrain Assessment), developed by Dean Straw N6BV. HFTA is available on the latest ARRL Antenna Book CD-ROM. HFTA shows visually how the elevation angles of a horizontal dipole, Yagi or stacked Yagis cover the statistical distribution of elevation angles that are necessary for communication via the ionosphere from one location to another.

We must always remember this simple truth:
The ionosphere controls the elevation angles, not our transmitting antenna!
HFTA ~ the Local Terrain to Europe

DeLorme Topo USA 7.0

Antenna Height

From “MicoDEM” USGS

Flat (EZNEC)
HFTA ~ “Primer”

Effect of the terrain on this dipole @ 4º: +10 dB

Frequency of Analysis

Freq. = 14.2 MHz
Max. Gain: 5.4 dBi

Terrain / Antenna

W1DYJ-10-60.00.PRO
18 ft
Dipole
Fig. of Merit: -1.7

Elev. Statistic

W1MA-EU.PRN

From W1 → Europe: % QSOs vs. Takeoff Angle
HFTA: Europe ~ 60°

80M (3.666 MHz)  40M (7.044 MHz)  20M (14.15 MHz)

HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03

Gain, dBi

Elevation Statistics, %

Takeoff Angle, Degrees

Terrain Profile

Height, feet a.s.l.

Distance from Tower Base, Feet

(C)Tower
HFTA: Africa ~ 90°

80M (3.666 MHz) 40M (7.044 MHz) 20M (14.15 MHz)

HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03

Gain, dB

Elevation Statistics, %

Takeoff Angle, Degrees

Terrain Profile

Height, feet ASL

Distance from Tower Base, Feet

Print

Close

(C)Tower
HFTA: South America ~ 170°

80M (3.666 MHz.)

40M (7.044 MHz.)

20M (14.15 MHz.)

HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03

HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03

HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03

Terrain Profile

Distance from Tower Base, Feet
HFTA: Japan ~ 336°

80M (3.666 MHz.)

40M (7.044 MHz.)

20M (14.15 MHz.)

HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03

Gain, dB

Elevation Statistics, %

Takeoff Angle, Degrees

Terrain Profile

Height, feet a.s.l.

Distance from Tower Base, Feet
Summarize: Effect of Terrain

The Effect of the Local Terrain

<table>
<thead>
<tr>
<th></th>
<th>Europe</th>
<th>Africa</th>
<th>S. America</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>80M</td>
<td>0</td>
<td>++</td>
<td>-</td>
<td>+/-</td>
</tr>
<tr>
<td>40M</td>
<td>++</td>
<td>++</td>
<td>+/-</td>
<td>0</td>
</tr>
<tr>
<td>20M</td>
<td>+</td>
<td>+</td>
<td>+/-</td>
<td>++</td>
</tr>
</tbody>
</table>

How can I improve on these dipoles? → Next
Potential Improvements

→ Will making them higher help much?
  • **EZNEC** with dipole centers @ 36’ (rather than 18’)
  • **HFTA** with 20M dipole center = 18’ & 36’

→ What about a different antenna on 20M?
  • **HFTA**: Dipole 2 18’ vs. 2 el Yagi & 3 el Yagi @ 32’
Potential Improvement?

Original
@ 18’ center
~ 1/14 λ

@ 36’ center
~1/7 λ

@ Azimuth = 60°

<table>
<thead>
<tr>
<th>Elevation °</th>
<th>Gain @ 18’ Elevation</th>
<th>Gain @ 36’ Elevation</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>3.9 dBi</td>
<td>7.0 dBi</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>-5.6</td>
<td>-5.2</td>
<td>-2.7 dB</td>
</tr>
<tr>
<td>10</td>
<td>-8.9</td>
<td>-9.3</td>
<td>-3.5</td>
</tr>
<tr>
<td>5</td>
<td>-12.8</td>
<td>-13.4</td>
<td>-3.7</td>
</tr>
</tbody>
</table>
Potential Improvement?

Original
@ 18’ center
~ 1/7 \( \lambda \)

@ 36’ center
~1/4 \( \lambda \)

@ Azimuth = 60°

<table>
<thead>
<tr>
<th>Elevation °</th>
<th>Gain @ 18' Elevation</th>
<th>Gain @ 36' Elevation</th>
<th>( \Delta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>4.8 dBi</td>
<td>6.3 dBi</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>-1.6</td>
<td>-1.1</td>
<td>-1.0 dB</td>
</tr>
<tr>
<td>10</td>
<td>-5.0</td>
<td>-5.2</td>
<td>-1.7</td>
</tr>
<tr>
<td>5</td>
<td>-9.1</td>
<td>-9.6</td>
<td>-1.3</td>
</tr>
</tbody>
</table>
Potential Improvement?

20M ~ 14.15 MHz.

Original
@ 18’ center
~ 1/4 λ

@ 36’ center
~1/2 λ

@ Azimuth = 60°

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Gain @ 18’ Elevation</th>
<th>@ 36’ Elevation</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>6.0 dBi</td>
<td>-0.1 dBi</td>
<td>+6.1</td>
</tr>
<tr>
<td>20</td>
<td>1.3</td>
<td>+4.0</td>
<td>+5.3</td>
</tr>
<tr>
<td>10</td>
<td>-1.8</td>
<td>+0.8</td>
<td>+1.6</td>
</tr>
<tr>
<td>5</td>
<td>-5.9</td>
<td>-3.5</td>
<td>+2.4</td>
</tr>
</tbody>
</table>

Potential Improvement?

20M ~ 14.15 MHz.
Potential Improvement?

HFTA – 20M

Dipoles @ 18’ & 36’
(To Europe)

20M ~ 14.15 MHz.
Potential Improvement?

HFTA – 20M

Dipole @ 18’
2 El Yagi @ 32’
3 El Yagi @ 32’

(To Europe)
Conclusions

Dipoles: raise center from 18’ to 36’

- 80M: doubling the height hurts some >> but \( \frac{1}{2} \lambda \) is 135’!
- 40M: doubling the height is a wash >> \( \frac{1}{2} \lambda \) is 66’
- 20M: helps by better than an S-Unit!

20M: need a “real” antenna

- Homebrew? Hexx Beam? Spiderbeam? SteppIR?
Modeling an 80/40/20M Fan Dipole for DX

Appendix

- Saltwater Analysis
- Other HF Bands
Salt Water Analysis

Effect of Location – what about the cove?
Does it help low angle radiation?

Theory: Salt water affects vertical antennas more than horizontals.
Effect of Salt Water—what about the cove?

Theory: Salt water affects vertical antennas more than horizontals.

Effect of Salt Water—what about the cove?

Theory: Salt water affects vertical antennas more than horizontals.

Previous plots assumed average soil:

- Conductivity = 0.005 Siemens/meter
- Dielectric Constant = 13

Actual location:

- Salt water ~400’ to the North West
- ~1000’ to the East

For Salt Water:

- Conductivity = 5 Siemens/meter
- Dielectric Constant = 81

Experiment:

- “Average” soil for 400’ circle
- Salt Water beyond that
**Effect of Salt Water → Europe @ Elevation = 20°**

**“Average” Soil**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Δ</th>
<th>Power Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>80M</td>
<td>-9.5 dBi</td>
<td>3.9 dBi</td>
</tr>
<tr>
<td>40M</td>
<td>-6.4 dBi</td>
<td>4.8 dBi</td>
</tr>
<tr>
<td>20M</td>
<td>-4.7 dBi</td>
<td>6.0 dBi</td>
</tr>
</tbody>
</table>

**Salt Water at 400’ radius**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Δ</th>
<th>Power Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>80M</td>
<td>-9.5 dBi</td>
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</tr>
<tr>
<td>40M</td>
<td>-6.4 dBi</td>
<td>4.8 dBi</td>
</tr>
<tr>
<td>20M</td>
<td>-4.7 dBi</td>
<td>6.0 dBi</td>
</tr>
</tbody>
</table>

There is no difference!
Effect of Salt Water → Europe @ Elevation = 20°

“Average” Soil

Salt Water everywhere (but house doesn’t float!)

Don’t use horizontal dipoles on a houseboat!
Modeling an 80/40/20M Fan Dipole for DX

Other HF Bands
EZNEC patterns
60M ~ 5.3 MHz.
Height = ±0.09λ
SWR ~ 7.2:1
EZNEC patterns
30M ~ 10.1 MHz
Height = ± 0.18λ
SWR ~ 6.4:1
11.2 MHz. 3.9:1

<table>
<thead>
<tr>
<th>Total Field</th>
<th>EZNEC+</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 dB</td>
<td></td>
</tr>
<tr>
<td>10.1 MHz</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Azimuth Plot</th>
<th>Cursor Az</th>
<th>115.0 deg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation Angle</td>
<td>35.0 deg.</td>
<td>Gain 5.89 dBi</td>
</tr>
<tr>
<td>Outer Ring</td>
<td>9.14 dBi</td>
<td>-0.38 dBi max</td>
</tr>
<tr>
<td>3D Max Gain</td>
<td>9.14 dBi</td>
<td>-3.25 dBi max3D</td>
</tr>
<tr>
<td>Slice Max Gain</td>
<td>6.26 dBi @ Az Angle = 105.0 deg.</td>
<td></td>
</tr>
<tr>
<td>Front/Back</td>
<td>0.42 dB</td>
<td></td>
</tr>
<tr>
<td>Beamwidth</td>
<td>50.5 deg.; -3dB @ 79.6, 130.1 deg.</td>
<td></td>
</tr>
<tr>
<td>Sidelobe Gain</td>
<td>6.02 dBi @ Az Angle = 280.0 deg.</td>
<td></td>
</tr>
<tr>
<td>Front/Sidelobe</td>
<td>0.24 dB</td>
<td></td>
</tr>
</tbody>
</table>
EZNEC patterns
17M ~ 18.1 MHz
Height = ±0.32λ
SWR ~ 4.5:1

18.95 MHz
3.5:1

17.5 18.5 19.5
1 10
EZNEC patterns
15M ~ 21.2 MHz
Height = ± 0.37λ
SWR ~ 5.6:1

22.25 MHz
SWR ~ 2.5:1
EZNEC patterns

12M ~ 24.95 MHz
Height = ±0.46λ

26.6 MHz.

SWR ~ 4.8:1

3.2:1
EZNEC patterns
10M ~ 28.3 MHz
Height = ± 0.55λ
SWR ~ 5.8:1
Modeling an 80/40/20M Fan Dipole for DX

Thank You

www.qsl.net/w1dyj