Gain and Performance Data of 144 MHz Antennas

Rainer Bertelsmeier

DJ9BV
Gluecksburger Str. 20
2 Hamburg 50

1. Antenna-Simulation

The recent article [1] on gain and noise temperature of yagi antennas for 432 MHz probably has given some impressions on the performance of professional antenna simulation software. This package - NEC-II from LLL [2] - now has been applied to antennas designed for 144 MHz. The results are interesting.

As a reminder some remarks on the accuracy of the NEC-II simulation software. The applied method of moments for the numerical solution of the integral equations seems to achieve the following accuracy of the simulated radiation pattern:

Gain: $\pm 0{,}2dB$

Sidelobes:

- $\pm 0{,}5db$ up to -20 dB.
- $\pm 1{,}0db$ from -20 to -25 dB.
- $\pm 2{,}0db$ from -25 to -30 dB.
- Undetermined accuray < -30 dB.

2. Performance criteria

For judging the performance of a particular design several features have been evaluated. The most important figure of course is power gain, which includes all losses, that is power gain equals directive gain minus losses. The power gain is given as dbD - power gain referenced to a dipole- and as dBi - power gain referenced to an isotropic antenna. The difference is just 2.15 dB. Manufacturerers, who like larger numbers, prefer dBi and those, who want to confirm to the international IEC-Standard for antenna gain measurements, state power gain in dBD. Next there are some pattern features like level of first sidelobe, front to back ratio (F/B), the 3 dB angles of the main lobe in E (Horizontal plane) and in H (Vertical plane). Mechanical features are length in m and normalized length in wavelength λ.

For comparison of the gain figures the gain of all simulated antennas has been plotted (Figure 1). The gain curve fits smoothly through all types of DL6WU-designs and is described by the following equation:

$$GAIN\,[dBD] = 7.773 \cdot LOG\left(\frac{LENGTH}{\lambda}\right) + 9.28 \qquad [1]$$

The gain increases with a rate of 2.34 dB for an increase of 3 dB in boom length, i.e. doubling the length. That compares well with the curve in [5], which has been extracted from measurements. Only a few antennas and favourably the short ones have higher power gains than those given by this equation.

To provide a single figure for comparison a quality factor AQ is defined:

$$AQ = GAIN_{dBi} - 10 \cdot LOG\left(\frac{LENGTH}{\lambda}\right) \qquad [1]$$

AQ describes power gain normalized to boom length. AQ is a measure for quality of yagi-antenna design, i.e. how much gain is achieved per unit boom size in wavelengths. Yagi-Antennas with different boom length can be compared immidiately. AQ-Values greater than 10 indicate a good yagi design.

For comparison several somewhat 'exotic' antennas like colinears, quad's and scelet-slot's are included in the table.

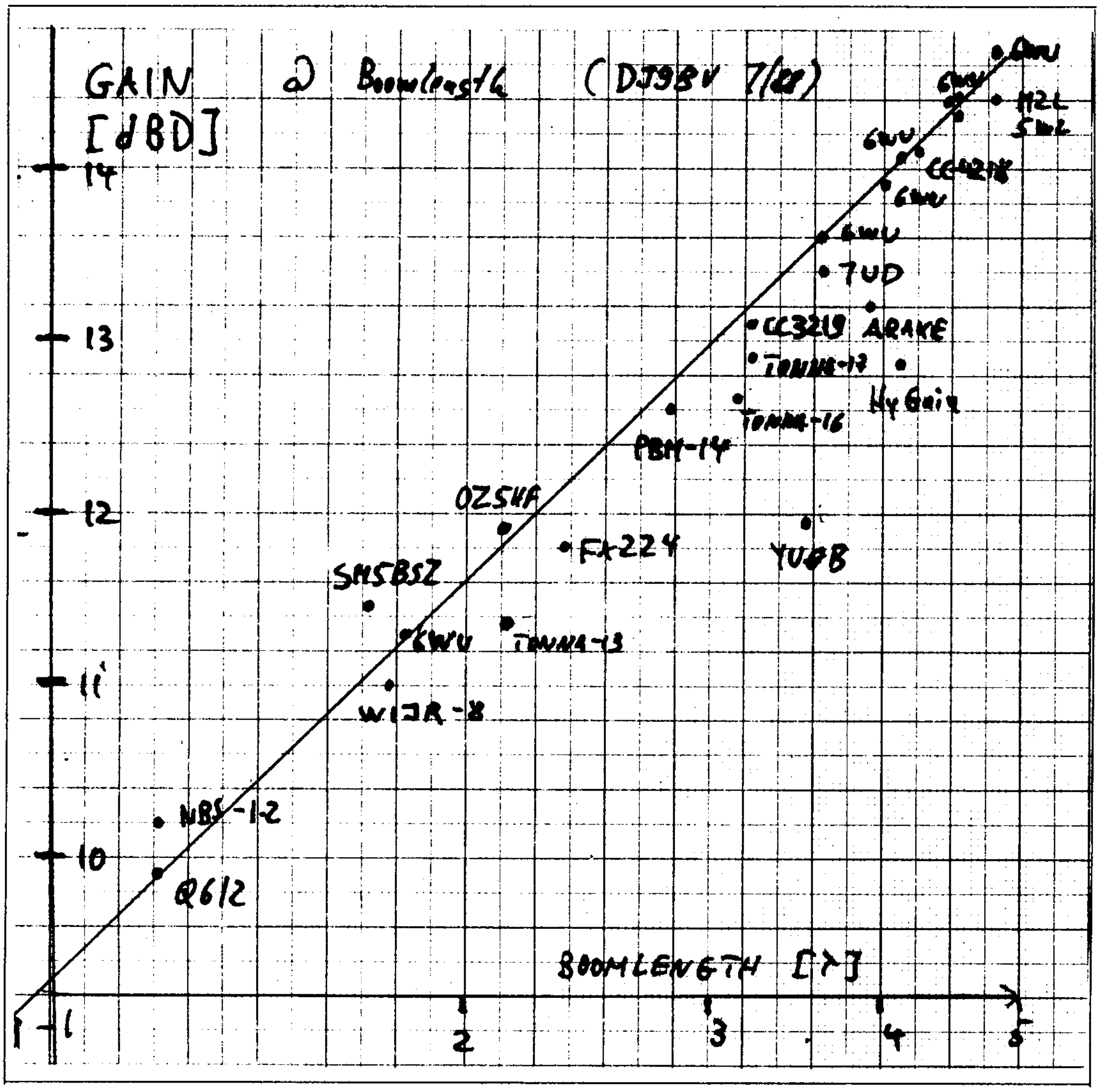


Figure 1: Yagi antenna gain versus boomlength

3. Simulation data

Table 1:

Performance data of 2 m Antennas @ 144.5 MHz (Calculated by DJ9BV)

TYPE	LENGTH		GAIN		EFFIC.	ANGLE @ -3dB		1. LOBE (E-Pat.)	F/B	AQ	DESIGN	Rem.
	[m]	λ	[dBD]	[dBi]	[%]	E [°]	H [°]	[dB]	[dB]	[dBi/λ]		
DX-120	0.49	0.5	12.95	15.1	99.8	47.8	21.3	-	28.1	-	Tonna	1
NBS-0.8	1.66	0.8	9.0	11.15	99.6	48.0	58.0	25.0	14.1	12.1	NBS	
Q6/2m	2.455	1.2	9.85	12.0	99.4	46.5	49.0	21.5	11.0	11.3	Jay-Beam	2
NBS-1.2	2.489	1.2	10.2	12.35	99.5	41.5	47.5	19.2	17.4	11.6	NBS	
SM5BSZ-6	3.511	1.69	11.45	13.6	98.4	35.0	38.50	16.4	10.8	11.3	Chen-Cheng	
W1JR-8	3.632	1.75	11.0	13.15	96.7	37.2	41.0	17.0	16.7	10.7	W1JR	
DJ9-2-1.8	3.75	1.8	11.3	13.45	98.5	39.0	44.0	19.2	20.2	10.9	DJ9BV	
TONNA-13	4.42	2.13	11.35	13.5	97.5	36.3	40.0	17.0	17.5	10.2	Tonna	
OZ5HF-9	4.5	2.17	11.9	14.05	99.0	36.5	40.0	17.4	24.4	10.7	OZ5HF	
FX-224	4.865	2.35	11.8	13.95	93.3	35.2	38.5	16.8	17.1	10.2	DL6WU	
PBM-14/HP	5.898	2.8	12.6	14.75	99.6	30.7	33.5	13.1	13.6	10.2	Jay-Beam	
TONNA-16	6.34	3.1	12.65	14.8	98.3	34.0	37.0	18.8	21.0	9.9	Tonna	
CueDee-15	6.444	3.1	12.9	15.04	98.7	33.0	35.5	17.5	21.5	10.1	CueDee	
TONNA-17	6.545	3.2	12.9	15.05	98.0	33.0	35.7	19.0	30.0	10.1	Tonna	
CC-3219	6.62	3.2	13.1	15.25	98.0	29.4	31.2	13.5	30.5	10.2	NBS	
YU0B	2x3.63	3.5	11.95	14.1	99.1	37.0	33.5	15.3	33.0	8.7	?	3
DJ7UD-15	7.41	3.6	13.4	15.55	96.7	30.7	33.5	20.0	21.9	10.0	DJ7UD	
DL6WU-15	7.42	3.6	13.6	15.75	98.7	30.5	32.5	18.2	36.0	10.2	DL6WU	
ARAKE-20	7.985	3.9	13.2	15.35	95.5	31.0	33.0	16.8	18.5	9.5	?	
DJ9-2-4.0	8.34	4.0	14.1	16.25	98.1	29.0	30.5	17.0	24.3	10.2	DL6WU	
HyGai215B	8.433	4.1	12.85	15.0	98.6	25.0	26.0	10.4	15.6	8.9	?	
LBX-16	8.509	4.1	14.05	16.2	98.0	28.0	29.5	15.6	22.6	10.1	DL6WU	
PA2VST	8.505	4.1	14.05	16.2	98.0	28.0	29.5	16.3	21.2	10.1	DL6WU	
CC-4218	8.722	4.2	14.1	16.25	97.5	27.0	28.5	15.4	18.5	10.0	NBS	
DJ9-2-4.4	9.18	4.4	14.4	16.55	98.1	28.0	29.5	17.0	21.0	10.1	DL6WU	
LBX-17	9.35	4.5	14.4	16.55	98.0	27.0	28.5	15.8	20.0	10.0	DL6WU	
Shark	9.4	4.5	14.3	16.45	98.7	27.0	28.5	15.9	19.5	9.9	?	
DJ9-2-4.8	10.02	4.8	14.65	16.8	98.1	27.5	28.8	17.2	22.0	10.0	DL6WU	
M2L-5WL	10.07	4.8	14.4	16.55	97.8	26.3	27.5	16.5	20.0	9.7	K6MYC	

Remarks:

1. Colinear antenna
2. Quad antenna
3. Scelet-Slot antenna (2 yagis)

4. Evaluation of simulation data

Before going into the details one observation should be stated very concise:

The figures claimed for the power gain of commercial antennas are too large very often. These overoptimistic specifications range up to **twice** the actual gain. That's a serious case of non-conservative marketing strategies and those manufacturers, who play the number game, should be observed carefully by the amateur community in the future.

4.1. List of Comments

For each antenna the type, manufacturer, the gain claimed, the gain simulated and the comparison of simulated gain with the gain of a yagi with the same length in DL6WU-design according to equation [1] is listed. By this comparison the state of the art of the individual manufacturer can be judged.

4.1.1. Tonna Antennas

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
DX-120	Tonna, France	?	12.95	-
Tonna-13	Tonna, France	14.35	11.35	-0.5
Tonna-16	Tonna, France	15.65	12.65	-0.4
Tonna-17	Tonna, France	13.1	12.9	-0.3

DX-120: The DX-120 is a 20 element collinear antenna. Gain compares very well with long yagis. Very good efficiency and good pattern.

Tonna-13: Gain simulated **2 dB** less than claimed. High sidelobes.

Tonna-16: Gain simulated **3 dB** less than claimed. Good pattern.

Tonna-17: Gain simulated .2 dB less than claimed. Good pattern (Figure 2).

Tonna gain claims vary between obscure (old designs) and rather accurate (new designs).

4.1.2. NBS Designs

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
NBS-0.8	?	9.2	9.0	+0.5
NBS-1.2	?	10.2	10.2	+0.3

NBS-0.8: Slightly less gain than specified in report.

NBS-1.2: Gain simulated confirms claim.

4.1.3. Jay Beam Antennas

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
Q6/2m	Jay Beam, Great Britain	12.0	9.85	0.0
PBM-14/HP	Jay Beam, Great Britain	14.5	12.6	-0.15

Q6/2m: Gain simulated is **2.15 dB** less than claimed. A severe case of wrong specification. Bad pattern. This quad type antenna has even worse gain than an equal length antenna as the NBS-1.2.

PBM-14/HP: Gain simulated **1.9 dB** less than claimed. Very bad pattern (Sidelobes and back lobe, see Figure 3). Version with thinner elements (9.1 mm instead of 12.7 mm) has better pattern, but same gain.

4.1.4. SM5BSZ-6

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
SM5BSZ-6	SM5BSZ	11.5	11.45	+0.4

Comment: Gain simulated confirms claim. The design is an experimental revision of the Chen-Cheng design, which does not function on its stated design wavelength. Antenna has bad back lobe and very narrow gain bandwith. Also input impedance is difficult to match.

4.1.5. W1JR-8

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
W1JR-8	W1JR	>10.85dBD(13.0dBi)	11.0	-0.2

Comment: Gain simulated confirms claim. Antenna seems to be tuned too low in frequency: symptoms are filled pattern and low efficiency.

4.1.6. DJ9BV Antennas

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
DJ9-2-1.8	DJ9BV	11.3	11.3	+0.0
DJ9-2-4.0	DJ9BV	14.1	14.1	+0.1
DJ9-2-4.4	DJ9BV	14.4	14.4	+0.1
DJ9-2-4.8	DJ9BV	14.65	14.65	+0.1

Comment: Reference antennas for comparison only. Classical DL6WU-Design improved by some computer verified changes.

4.1.7. OZ5HF-9

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
OZ5HF-9	SHT-Design, Denmark	13.0	11.9	+0.1

Comment: Gain simulated 1.1 dB less than claimed. Very good pattern and good efficiency (Figure 4).

4.1.8. FX224

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
FX224	HAG, Germany	12.4	11.8	-0.4

Comment: Gain simulated 0.6 dB less than claimed. Good pattern, but high back lobe. Low efficiency because of steel elements.

4.1.9. CueDee-15

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
CueDee-15	CueDee	?	12.9	-0.2

Comment: Good gain. Good pattern.

4.1.10. CushCraft Antennas

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
CC3219	CushCraft, USA	16.2	13.1	-0.1
CC4218	CushCraft, USA	17.2	14.1	0.0

CC3219: Gain simulated **3 dB** less than claimed. NBS design with 3.2 wavelenght boom length. In spite of unprofessional exaggerated claim actual gain is state of the art, but high sidelobes.

CC4218: Gain simulated **3 dB** less than claimed. NBS design with 4.2 wavelenght boom length. In spite of unprofessional exaggerated claim actual gain is state of the art , but bad F/B in spite of trigonal reflector (Figure 5).

4.1.11. KLM Antennas

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
LBX-16	KLM, USA	14.5	14.05	0.0
LBX-17	KLM, USA	?	14.4	0.0

KLM-16: Gain simulated 0.45 dB less than claimed. DL6WU design with log-periodic feed structure. Good gain. Good Pattern. Bad matching. Better solution would be a straight dipole, because DL6WU-design will give excellent matching to 200 or 50 Ohms with balun.

KLM-17: One element more than KLM-16. See KLM-16.

4.1.12. YU0B

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
YU0B	?	13.75	11.95	-1.55

Comment: Gain simulated **1.8 dB** less than claimed. Good pattern and good efficiency, but low gain for mechanical size.

4.1.13. DJ7UD-15

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
DJ7UD-15	DJ7UD	(12.65+1.5)	13.4	-0.2

Comment: Gain simulated 0.75 dB less than claimed (DJ7UD states 1.5 dB more than Tonna-16). Good pattern.

4.1.14. DL6WU-15

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
DL6WU-15	DL6WU	13.6	13.6	0.0

Comment: Good gain. Very good pattern. Design is 9 years old, but still top of the crowd!

4.1.15. ARAKE-20

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
ARAKE-20	?	14.0	13.2	-0.7

Comment: Gain simulated 0.8 dB less than claimed. Bad efficiency.

4.1.16. HyGain215B

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
Hy-Gain215B	Hy-Gain, USA	15.65	12.85	-1.2

Comment: Gain simulated **2.8 dB** less than claimed. Very bad pattern and bad gain.

4.1.17. PA2VST

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
PA2VST	PA2VST	?	14.05	0.0

Comment: Same antenna as KLM-16 but with metric size elements (6 mm dia.).

4.1.18. Shark

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
Shark	Shark	?	14.3	0.0

Comment: Good gain. Ordinary pattern.

4.1.19. M2L-5WL

Type	Manufacturer	Gain claimed [dBD]	Gain simulated [dBD]	Difference to DL6WU-Yagi [dB]
M2L-5WL	K6MYC	15.0	14.4	-0.2

Comment: Gain simulated 0.6 dB less than claimed, but good gain. Ordinary pattern.

5.

Acknowledgements: I have to thank DC4XH, DF5LQ, DL6WU, DL8HCZ, DL8LAQ, OE6WMG and K1FO for kindly support in providing the necessary mechanical dimensions of the simulated antennas.

6. References

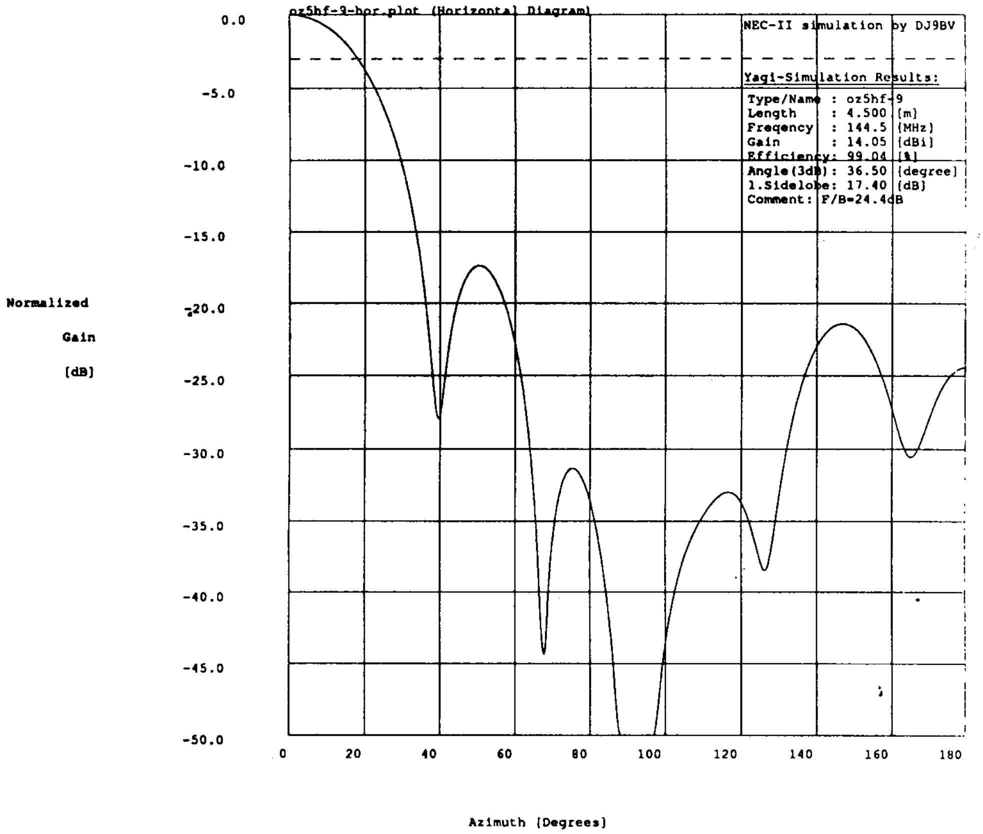
[1] R. Bertelsmeier, "Effective Noise Temperatures of 4-Yagi-Arrays for 432 MHz EME", DUBUS 4(1987), , pp. 32-40

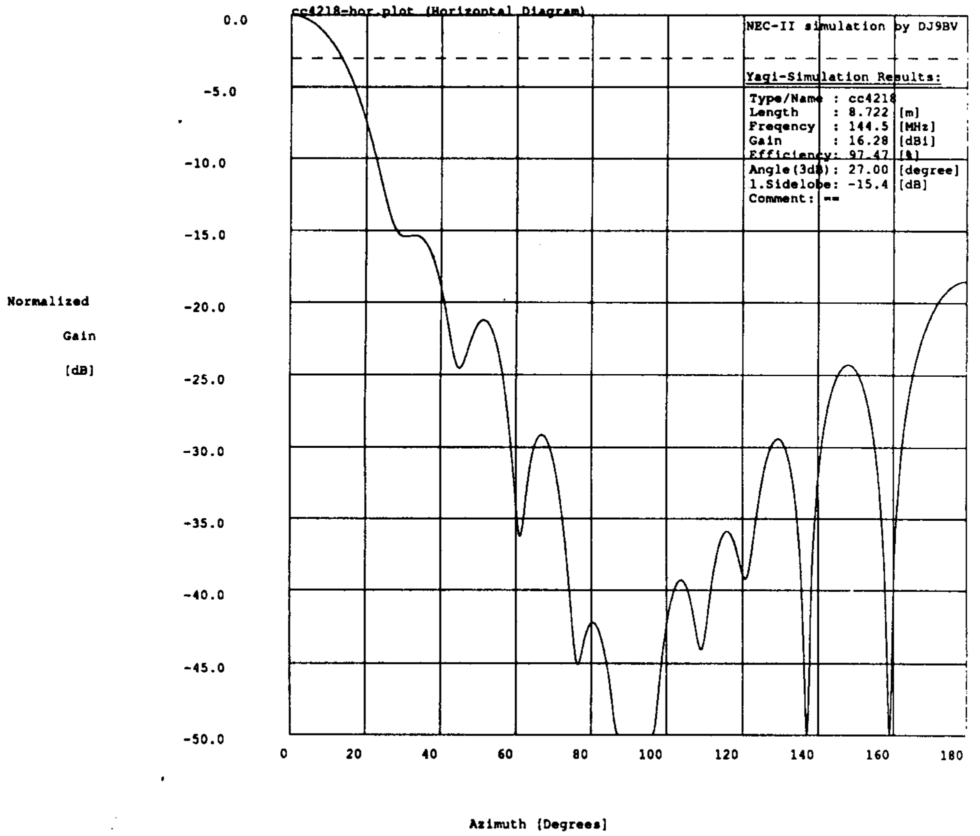
[2] G.J. Burke, A.J. Pogio, "Numerical Electrodynamics Code (NEC) - Method of Moments", NOSC TD 116, Vol. 1, 1981, San Diego, USA

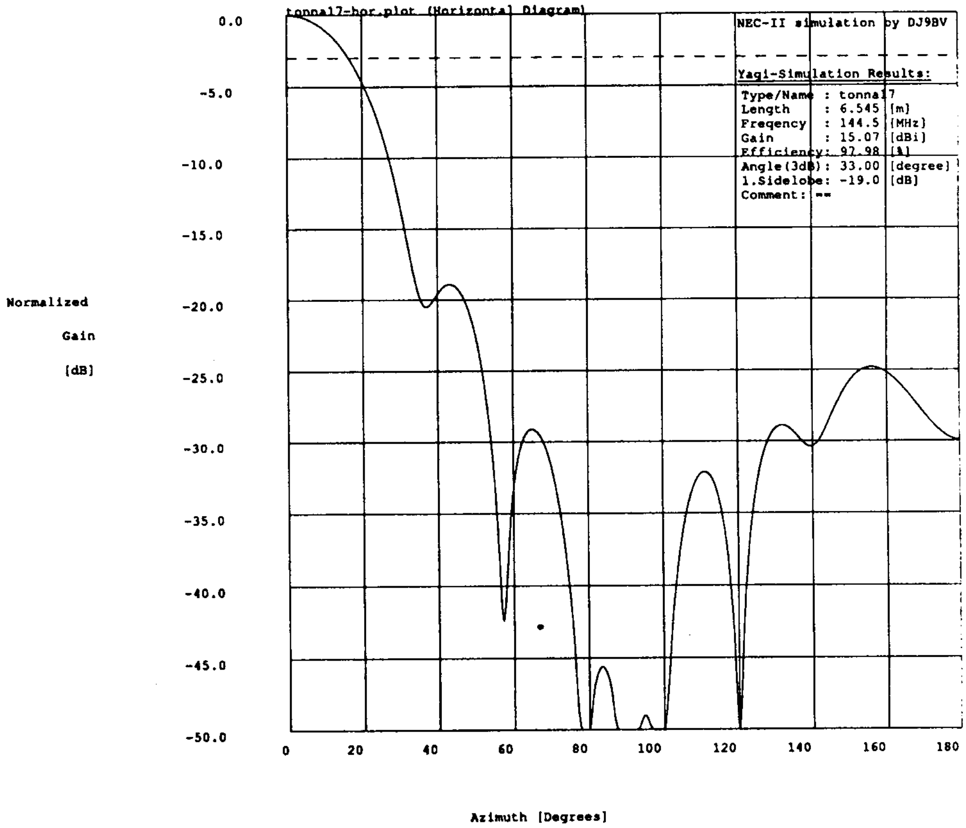
[3] G. Hoch, "Wirkungsweise und optimale Dimensionierung von Yagi-Antennen", UKW-Berichte 17(1977), Heft 1, S.27-36

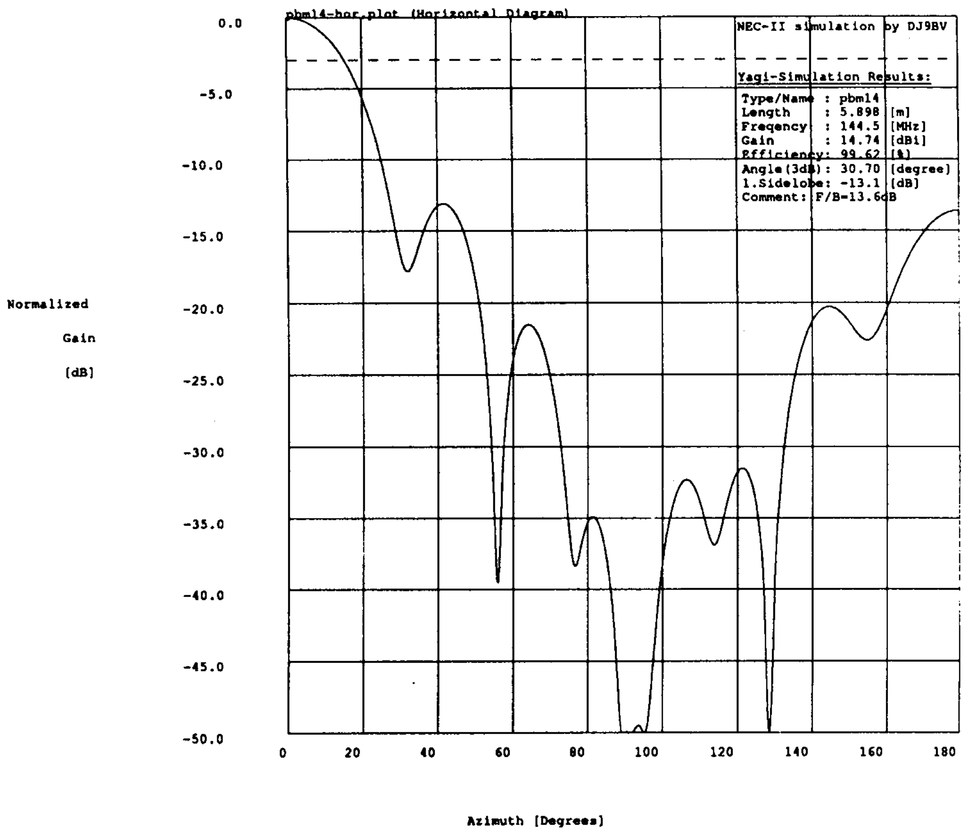
[4] G. Hoch, "Mehr Gewinn mit Yagi-Antennen", UKW-Berichte 18(1978), Heft 1, S.2-9

[5] G. Hoch, "Extrem lange Yagi-Antennen", UKW-Berichte 22(1982), Heft 1, S.3-11


oz5hf-9-hor.plot (Horizontal Diagram)
NEC-II simulation by DJ9BV
Yagi-Simulation Results:
Type/Name : oz5hf-9
Length : 4.500 [m]
Freqency : 144.5 [MHz]
Gain : 14.05 [dBi]
Efficiency: 99.04 [%]
Angle(3dB): 36.50 [degree]
1.Sidelobe: 17.40 [dB]
Comment: F/B=24.4dB
Normalized Gain [dB]
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
0 20 40 60 80 100 120 140 160 180
Azimuth [Degrees]


cc4218-hor.plot (Horizontal Diagram)
NEC-II simulation by DJ9BV
Yagi-Simulation Results:
Type/Name : cc4218
Length : 8.722 [m]
Freqency : 144.5 [MHz]
Gain : 16.28 [dBi]
Efficiency: 97.47 [%]
Angle(3dB): 27.00 [degree]
1.Sidelobe: -15.4 [dB]
Comment: ==
Normalized Gain [dB]
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
0 20 40 60 80 100 120 140 160 180
Azimuth [Degrees]


tonna17-hor.plot (Horizontal Diagram)
NEC-II simulation by DJ9BV
Yagi-Simulation Results:
Type/Name : tonna17
Length : 6.545 [m]
Freqency : 144.5 [MHz]
Gain : 15.07 [dBi]
Efficiency: 97.98 [%]
Angle(3dB): 33.00 [degree]
1.Sidelobe: -19.0 [dB]
Comment: --
Normalized Gain [dB]
Azimuth [Degrees]


pbm14-hor.plot (Horizontal Diagram)
NEC-II simulation by DJ9BV
Yagi-Simulation Results:
Type/Name : pbm14
Length : 5.898 [m]
Freqency : 144.5 [MHz]
Gain : 14.74 [dBi]
Efficiency: 99.62 [%]
Angle(3dB): 30.70 [degree]
1.Sidelobe: -13.1 [dB]
Comment: F/B=13.6dB
Normalized Gain [dB]
Azimuth [Degrees]