Yagi-Uda and Log-Periodic Antennas

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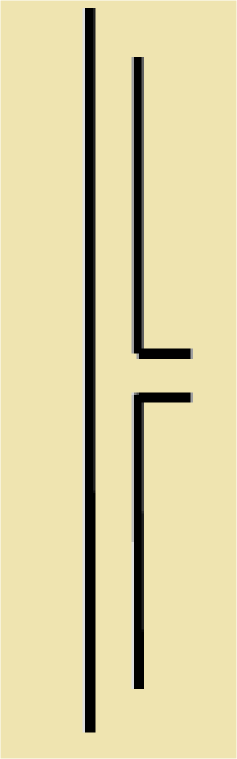
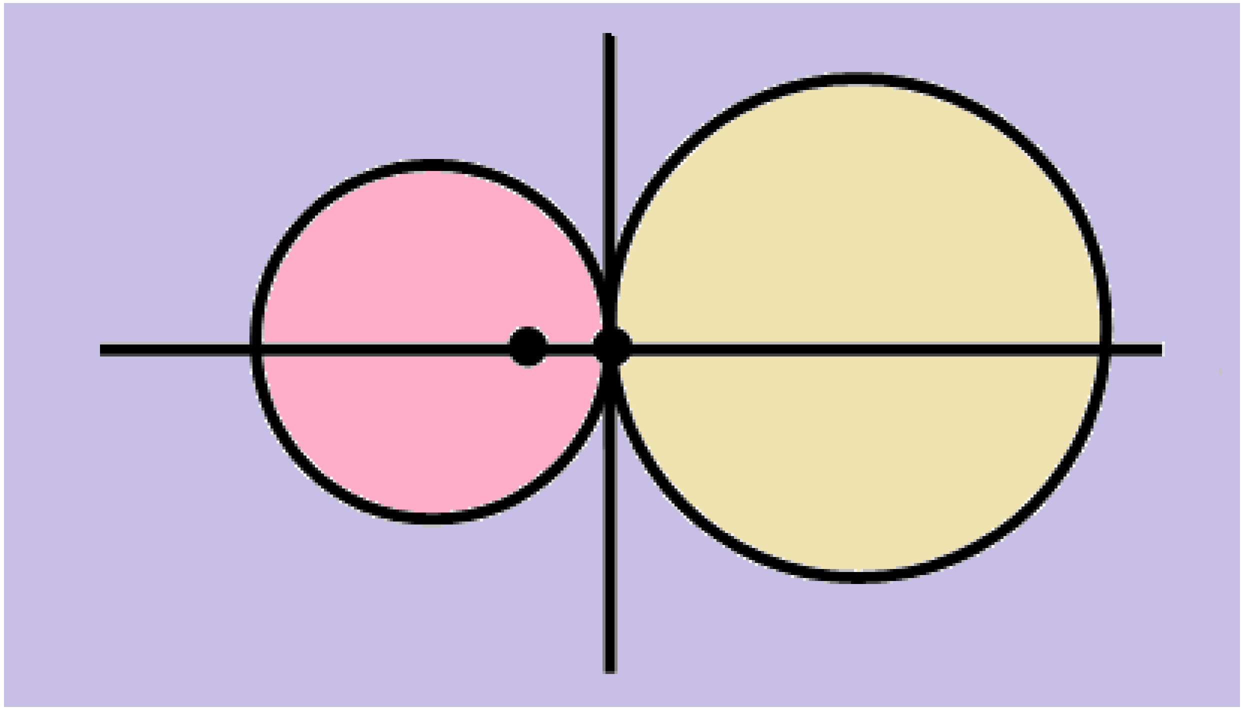
Unit No. : 04, Lecture No. : 5

Linear Dipole with a Reflector

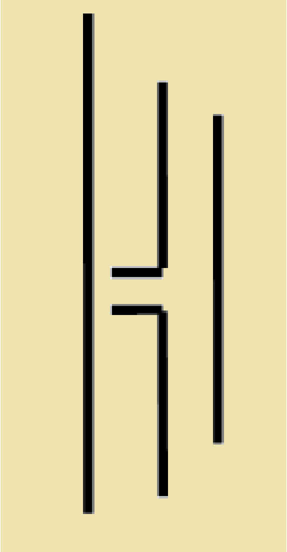


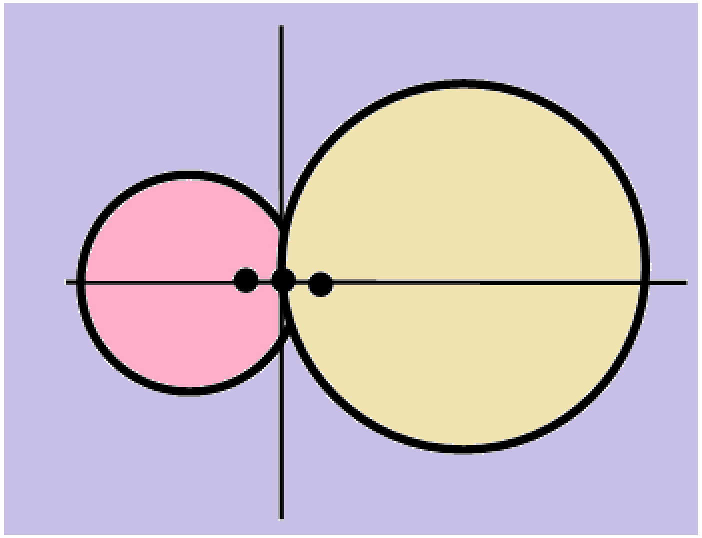


A linear dipole antenna has omni-directional radiation pattern. Gain ≈ 2 dB

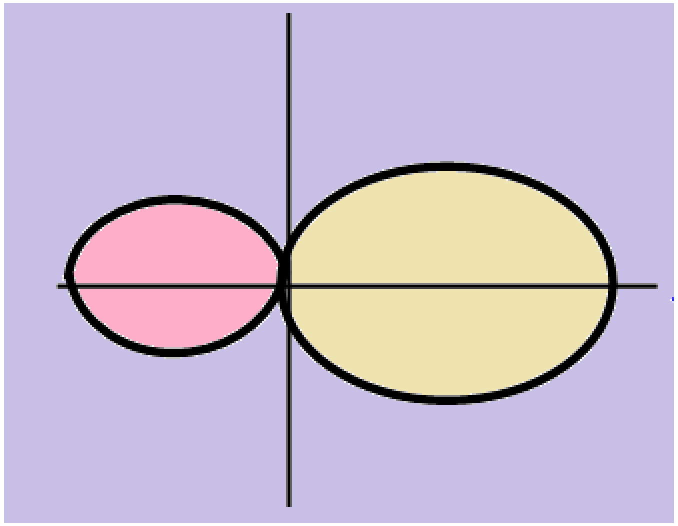
A dipole with a linear reflector will have directional radiation pattern with gain ≈ 5 dB

Yagi-Uda Antenna with 3-Elements





H-Plane Pattern



E-Plane Pattern

A 3-element Yagi-Uda Antenna has one fed dipole, one linear reflector and one director.

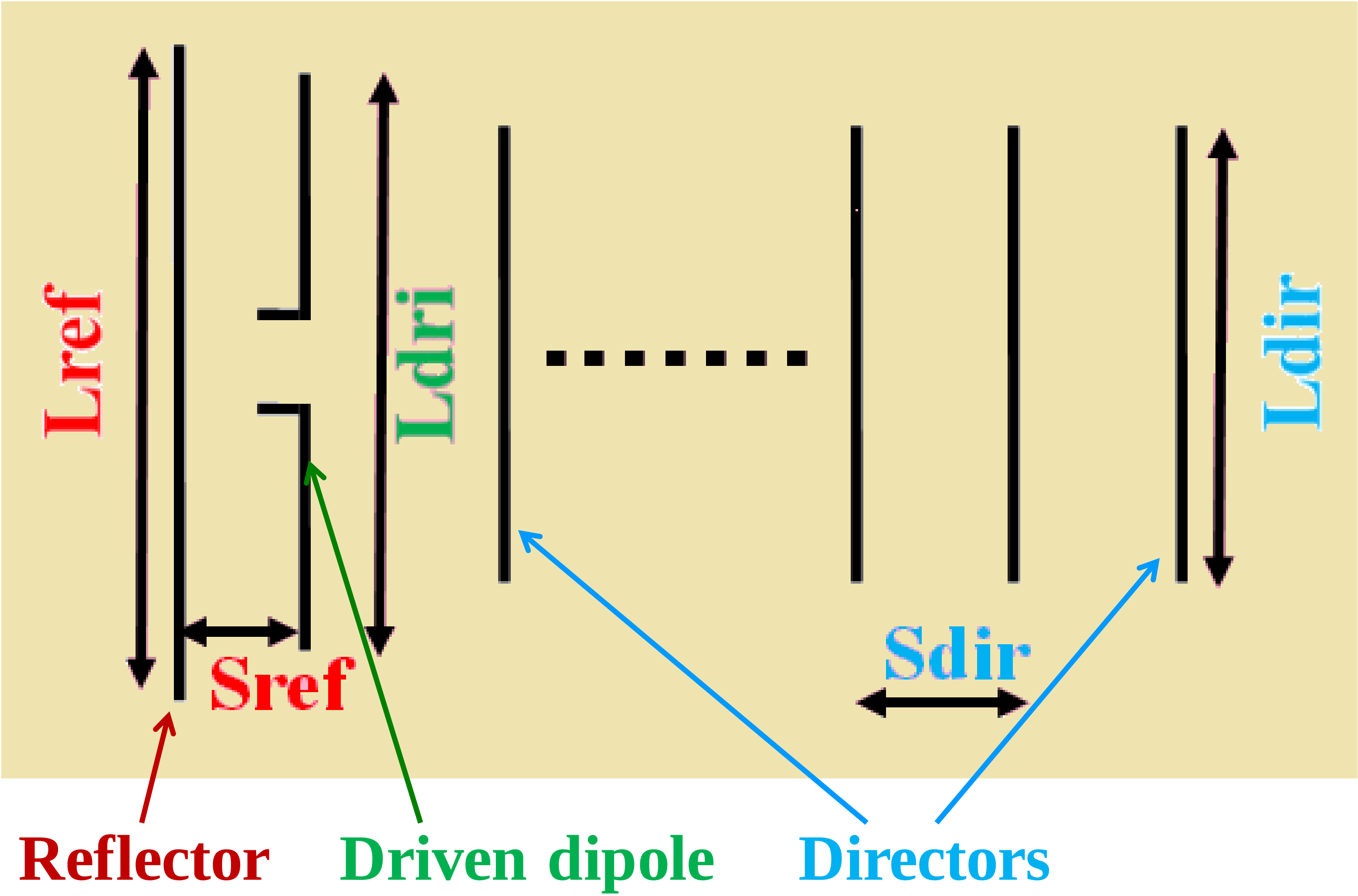
Length of the dipole: $l + d = 0.48\lambda$

Length of the reflector $> l >$ Length of the director

Spacing between the elements $\approx \lambda/4$

It acts as an end-fire array antenna. Gain ≈ 7 dB

General Yagi-Uda Antenna



Typical Values of Yagi-Uda Antenna

A. Director lengths: $(0.4 - 0.45)\lambda$

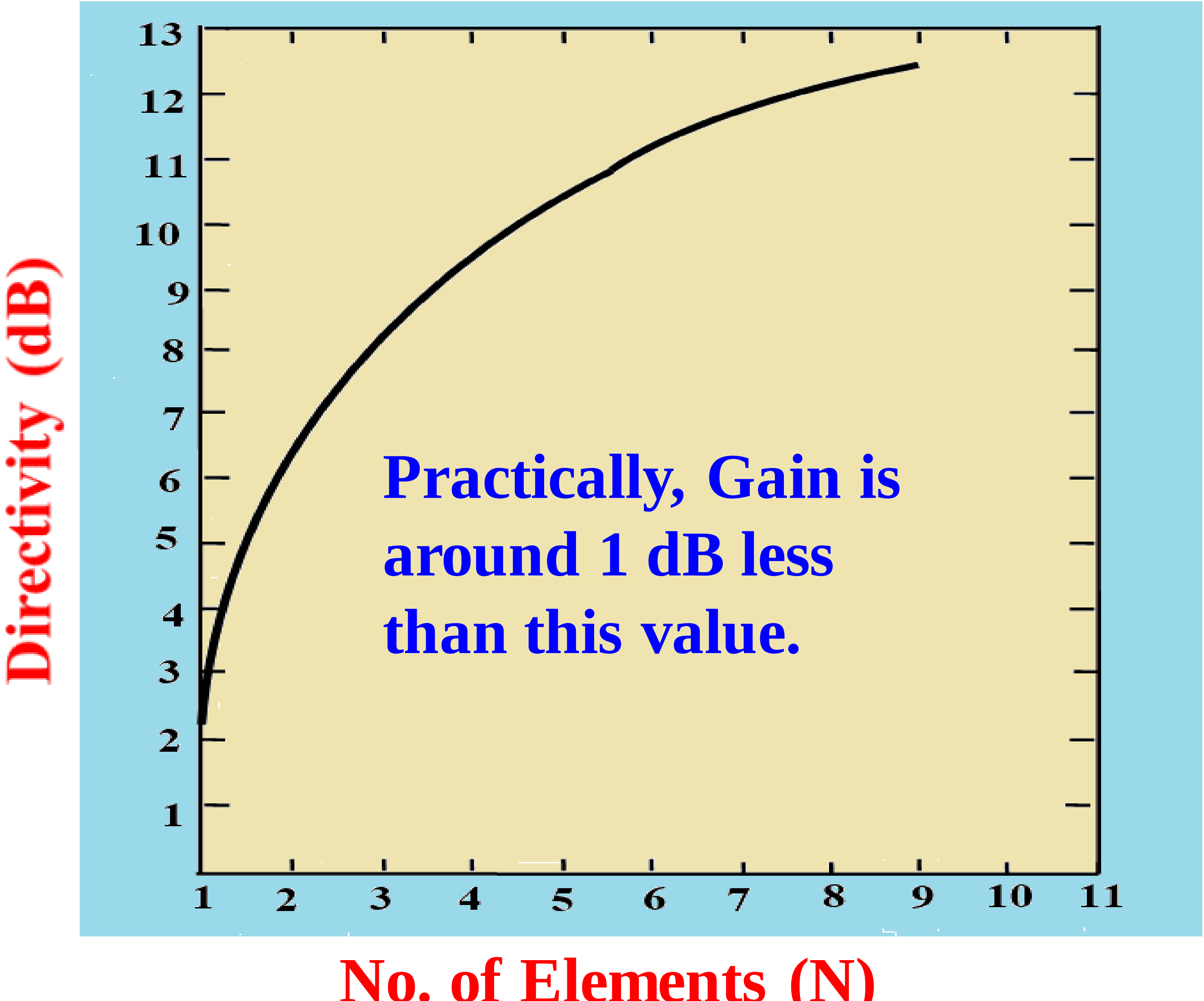
B. Feeder length: $(0.47 - 0.49)\lambda$
(usually Folded Dipole)(resonant)

C. Reflector length: $(0.5 - 0.525)\lambda$

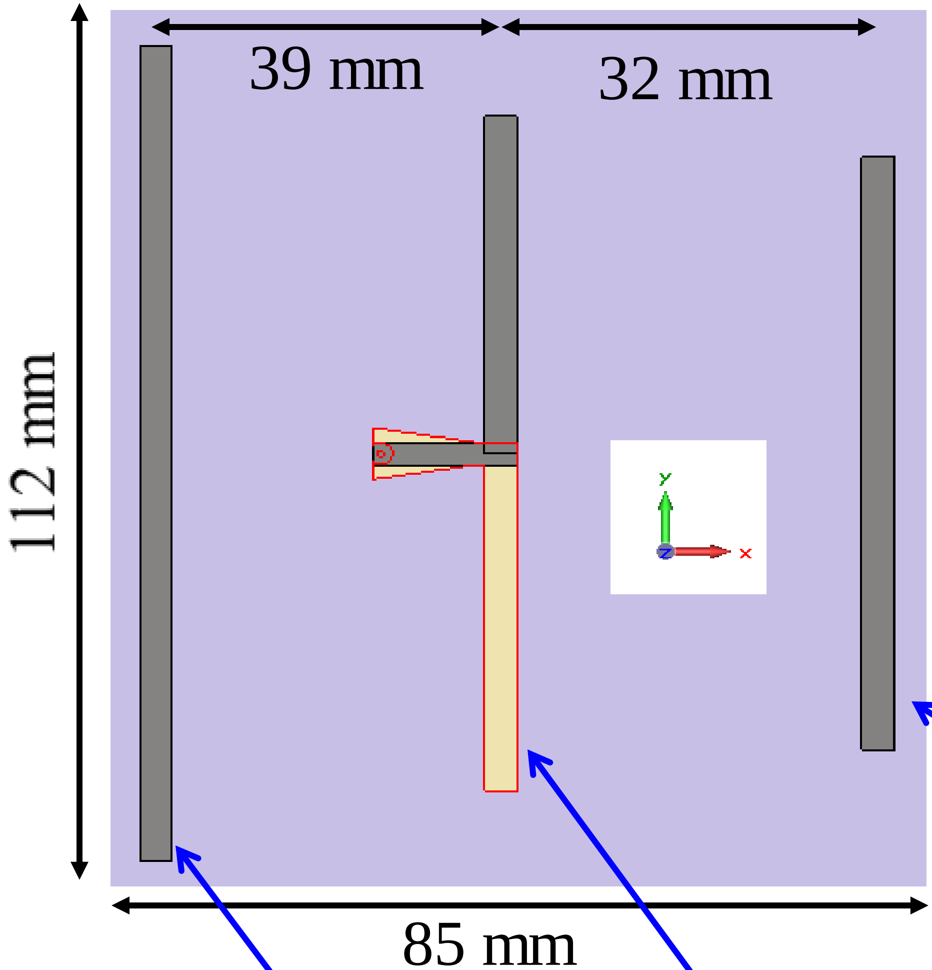
D. Reflector-feeder spacing : $(0.2 - 0.25)\lambda$

E. Director spacing: $(0.3 - 0.4)\lambda$

Directivity vs No. of Elements



3-Element Printed Yagi-Uda Antenna



Frequency : 1.3 GHz

λ = 230 mm

FR 4 Substrate:

ε_r = 4.4, h = 1.6 mm

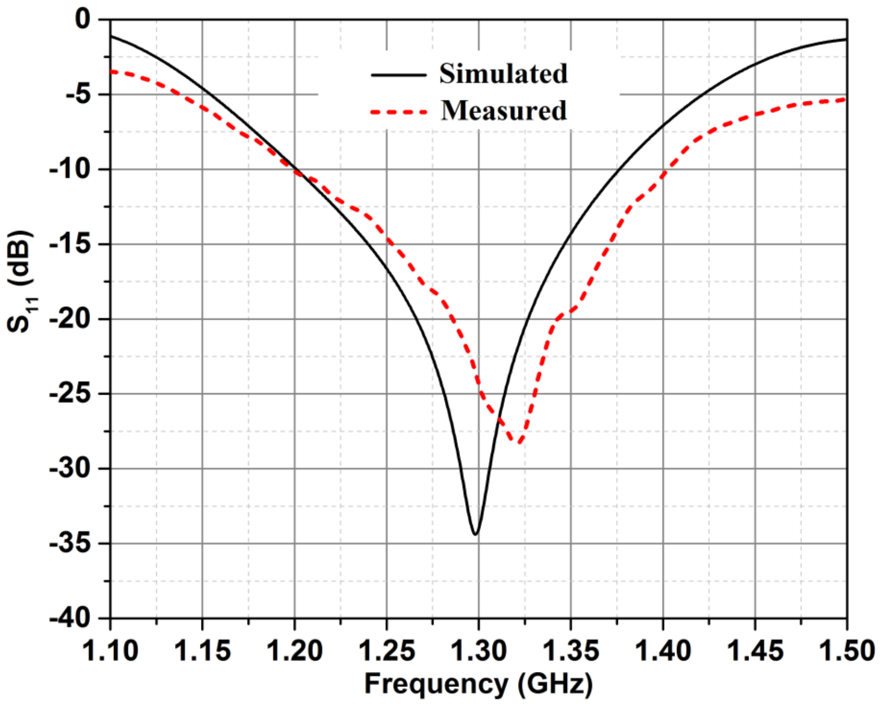
ε_{eff} ≈ 1.3-1.4 due to field in air

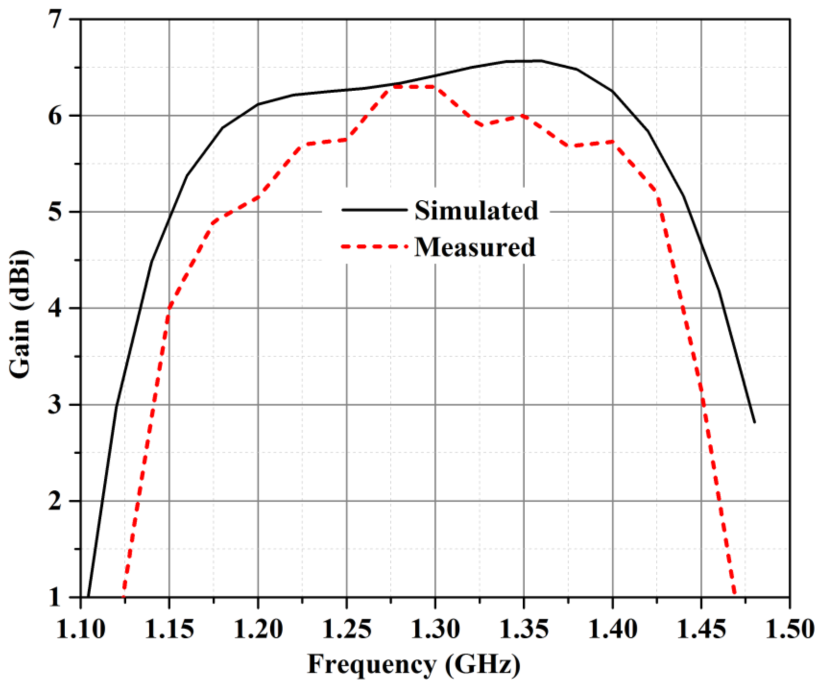
Length of Director = 72 mm

Length of Reflector = 102 mm

Length of Driven Dipole = 91 mm

Results of 3-Element Yagi-Uda Antenna

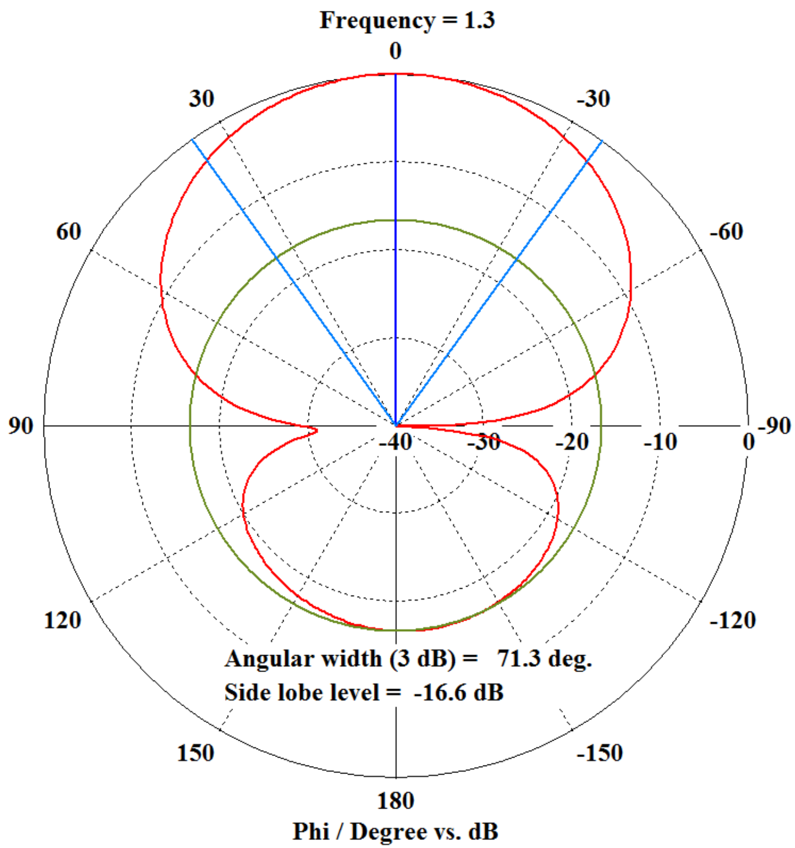


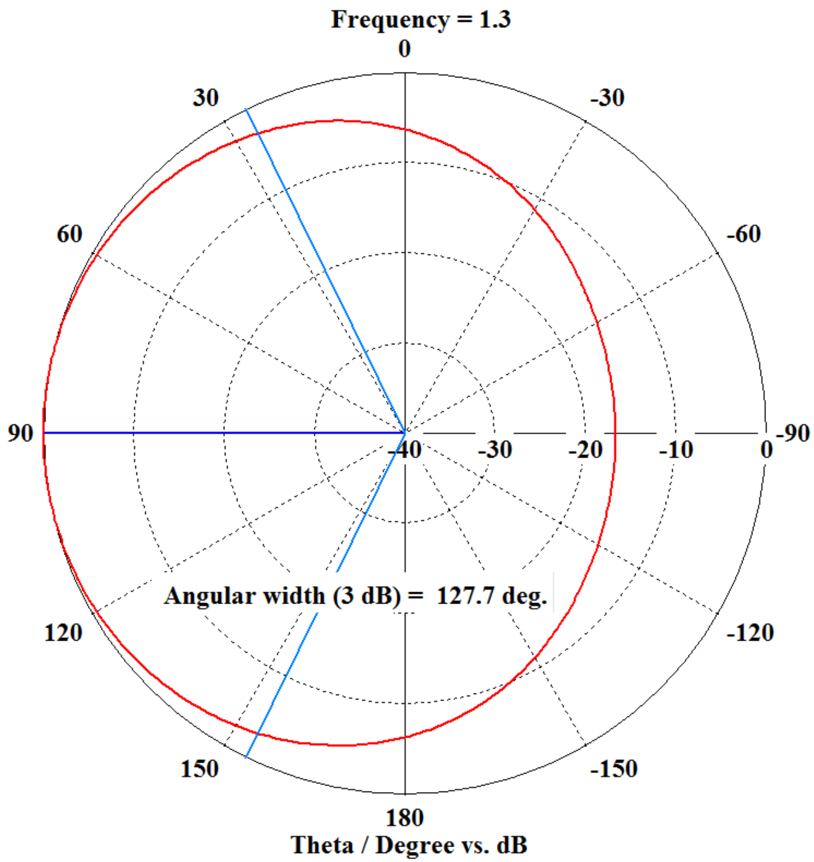


For $|S_{11}| \leq$ - 10 dB, Measured BW = 15.4%

Measure Peak Gain = 6.3 dB

Radiation Pattern at 1.3 GHz

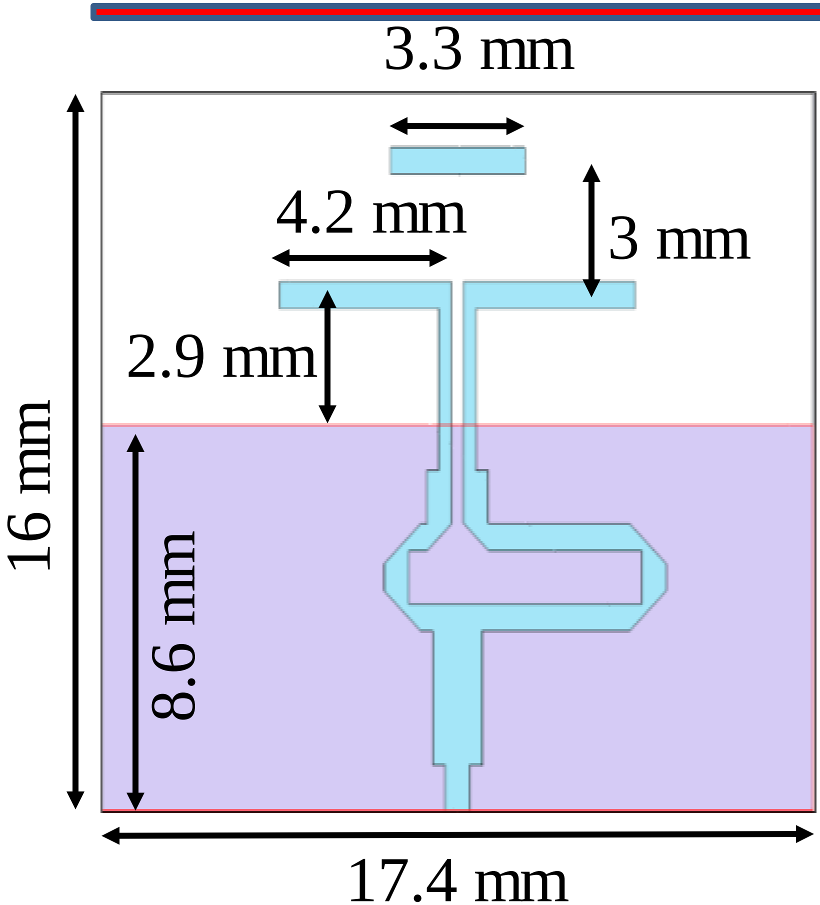


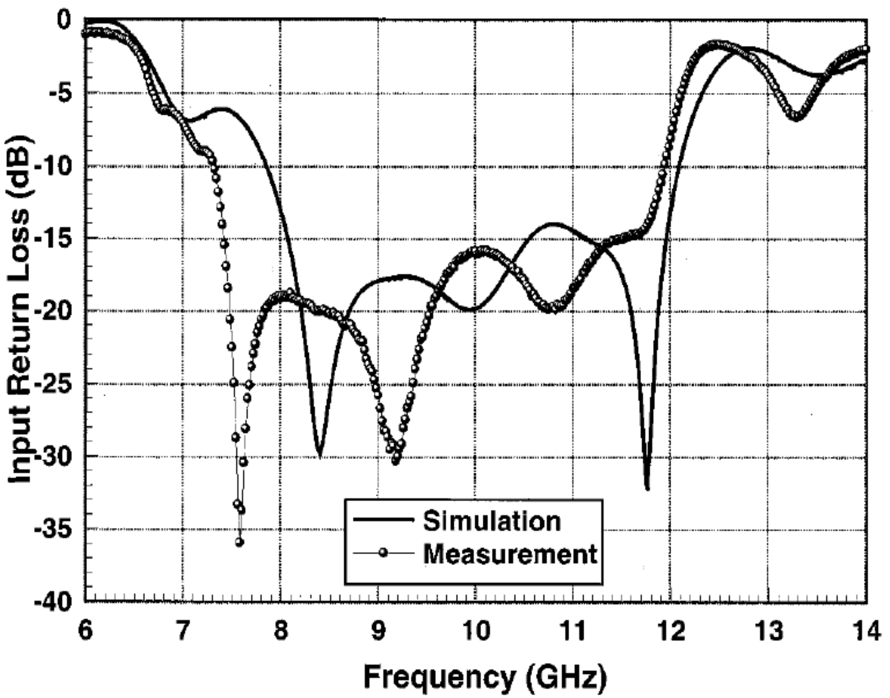


xy Plane – E Plane

xz Plane – H Plane

Broadband Planar Quasi-Yagi Antenna





Bandwidth: 48% at X-band

Gain: 3.4 - 5.1 dB

Substrate: ε_r = 10.2 and h = 0.635 mm

Another design given for lesser BW and larger Gain

N. Kaneda, W. R. Deal, Yongxi Qian, R. Waterhouse and T. Itoh, "A broadband planar quasi-Yagi antenna," in *IEEE Transactions on Antennas and Propagation*, vol. 50, no. 8, pp. 1158-1160, Aug. 2002.

Simplified Feed for Printed Yagi Antenna

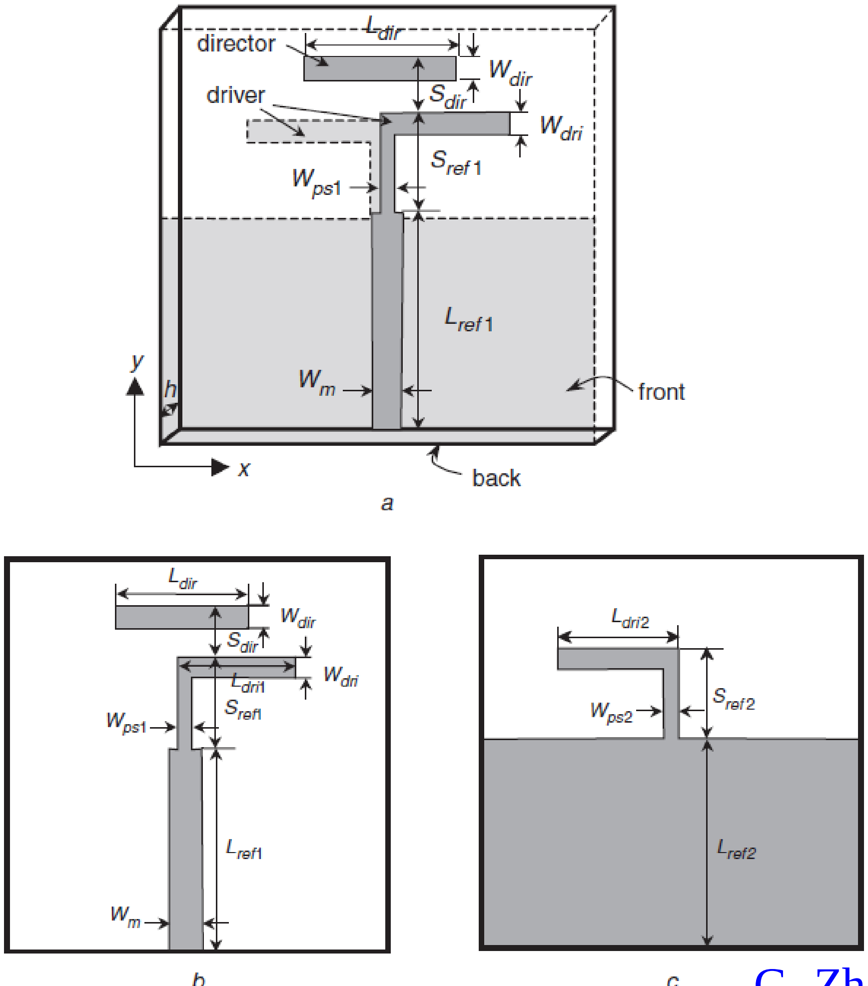


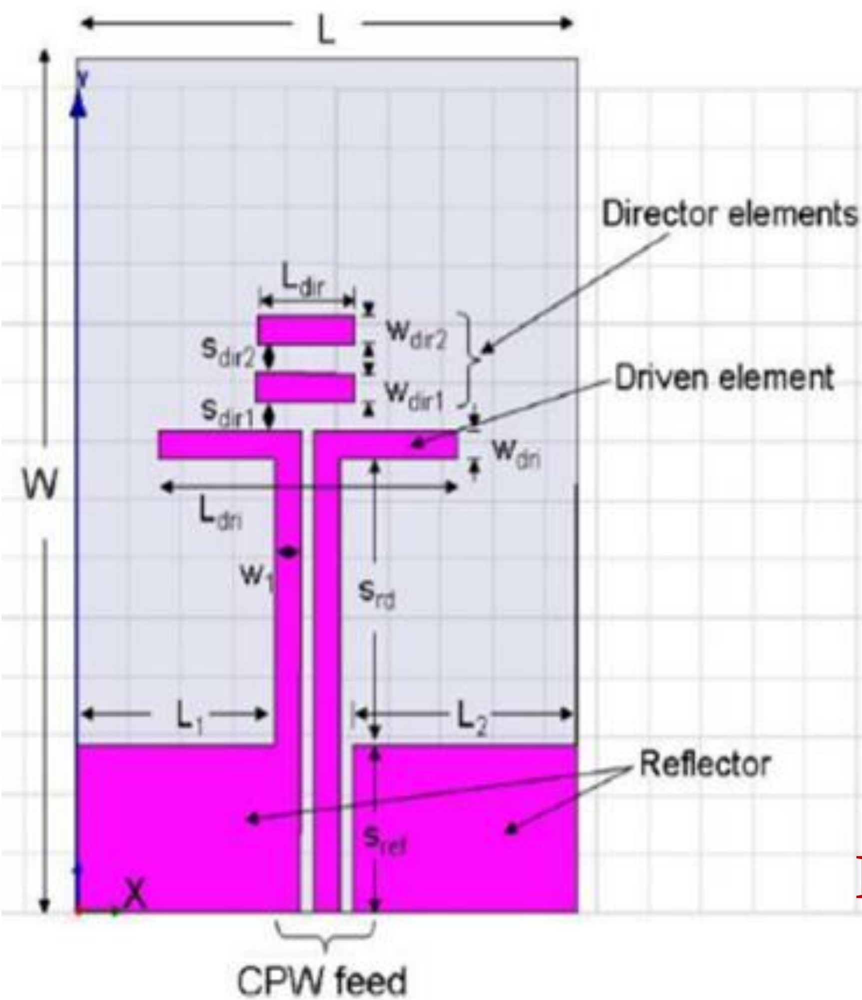
Fig. 1 *Geometry of modified printed Yagi antenna*
a 3D schematic diagram *b* Top layer
c Bottom layer

Lref1	16 mm
Ldir	2.84 mm
Sref1	7.5 mm
Sdir	2.58 mm
Wm	0.6 mm
Wdri	0.6 mm
Wdir	0.6 mm
Ldri1	4.23 mm

BW = 40% at X-band

G. Zheng, A. A. Kishk, A. W. Glisson and A. B. Yakovlev, "Simplified feed for modified printed Yagi antenna," in *Electronics Letters*, vol. 40, no. 8, pp. 464-466, 15 April 2004.

Broadband CPW-Fed Quasi-Yagi Antenna

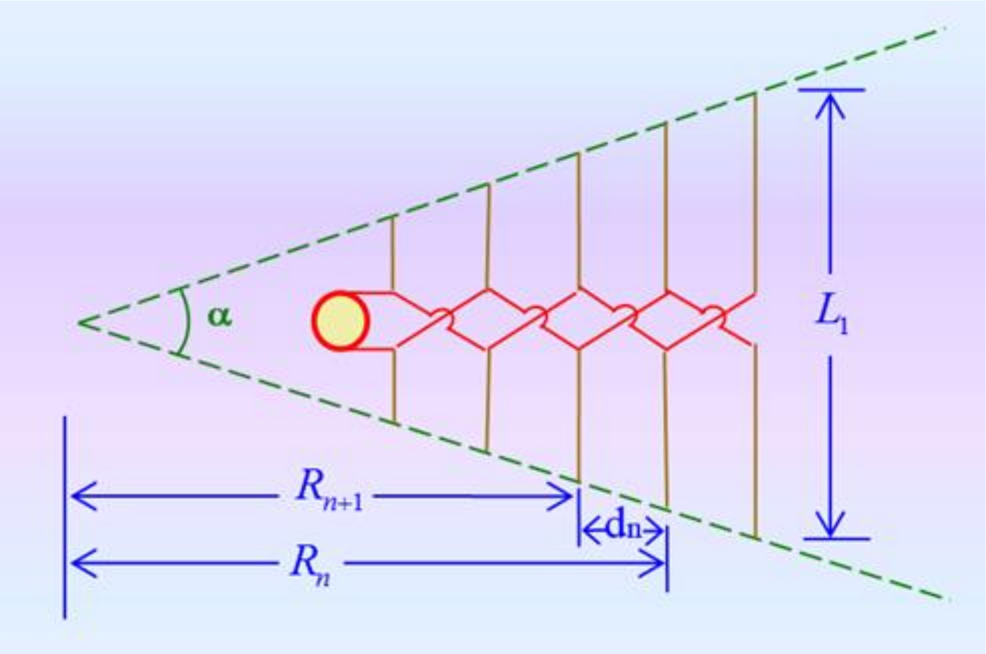


Sref	5.69 mm
Ldir	3.73 mm
L	19.2 mm
W	29 mm
Sdir1=Sdir2	0.96 mm
Wdir1=Wdir2	0.96 mm
L1	8.61 mm
L2	7.61 mm
Srd	9.69 mm
Lri	11.5 mm

Bandwidth = 44% at X-band
Peak Gain = 7.4 dB

H. K. Kan, R. B. Waterhouse, A. M. Abbosh and M. E. Bialkowski, "Simple Broadband Planar CPW-Fed Quasi-Yagi Antenna," in *IEEE Antennas and Wireless Propagation Letters*, vol. 6, pp. 18-20, 2007.

Log-Periodic Dipole Array Antenna



All dipole elements are fed with successive elements out of phase. Radiates in end-fire direction.

$$\tau = \frac{R_{n+1}}{R_n} = \frac{L_{n+1}}{L_n} = \frac{d_{n+1}}{d_n}$$

$$\tan\frac{\alpha}{2} = \frac{L_n/2}{R_n} = \frac{L_{n+1}/2}{R_{n+1}}$$

LPDA Design Equations

$$\sigma = \frac{d_n}{2L_n}$$

$$d_n = R_n - R_{n+1}$$

$$R_{n+1} = \tau R_n$$

$$R_n = \frac{L_n}{2\tan(\alpha/2)}$$

$$d_n = R_n - \tau R_n = (1-\tau)R_n$$

$$\sigma = \frac{d_n}{2L_n} = \frac{1-\tau}{4\tan(\alpha/2)}$$

$$\alpha = 2\tan^{-1}\left(\frac{1-\tau}{4\sigma}\right)$$

LPDA Design Formulas

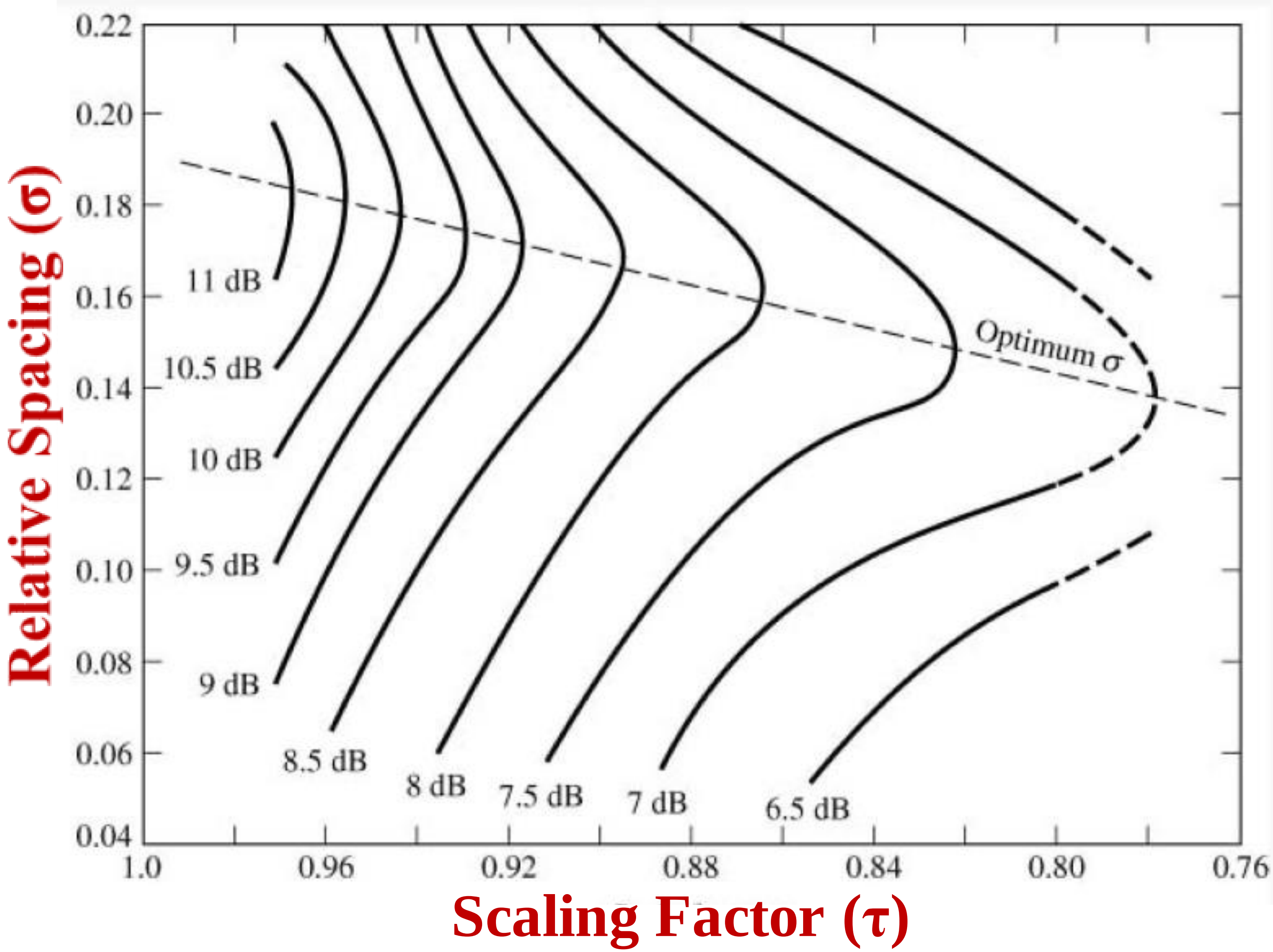
$$\boxed{L_1 \approx \frac{\lambda_L}{2}}$$

$$\boxed{L_N \approx \frac{\lambda_U}{2}}$$

Add one large dipole, which acts as reflector to increase gain at lower frequencies.

Add a few small dipoles in front, which act as directors to increase gain at higher frequencies.

Design Curve for LPDA for given Directivity



Design of LPDA Antenna

Example: **Design of a 54 to 216 MHz Log-periodic Dipole Antenna. Desired Gain: 6.5 dB**

Solution: For gain = 6.5 dB, optimum values of τ and σ are obtained from the design curve for Directivity = 7.5 dB (assuming 1 dB loss).

So, $\tau = 0.822$ and $\sigma = 0.149$. Therefore,

$$\boxed{\alpha = 2\tan^{-1}\left(\frac{1-0.822}{4(0.149)}\right) = 33.3^0}$$

Design of LPDA Antenna (Contd.)

Longest dipole length is calculated corresponding to lowest frequency = 54 MHz

$$\boxed{L_1 = 0.5\lambda_L = 0.5(5.55) = 2.78m}$$

Shortest dipole length is calculated corresponding to highest frequency = 216 MHz

$$\boxed{L_U = 0.5\lambda_U = 0.694m}$$

Design of LPDA Antenna (Contd.)

Length of other elements is calculated by scaling the largest dipole length (2.78 m) until the smallest dipole length (0.694 m) is obtained.

L_1 = 2.78 m, L_2 = 2.29 m, L_3 = 1.88 m,
L_4 = 1.54 m, L_5 = 1.27 m, L_6 = 1.04 m,
L_7 = 0.858 m, L_8 = 0.705 m, L_9 = 0.579 m.
So, N = 9.

One or two elements can be added at both the end to improve the performance at the cut-off.

Design of LPDA Antenna (Contd.)

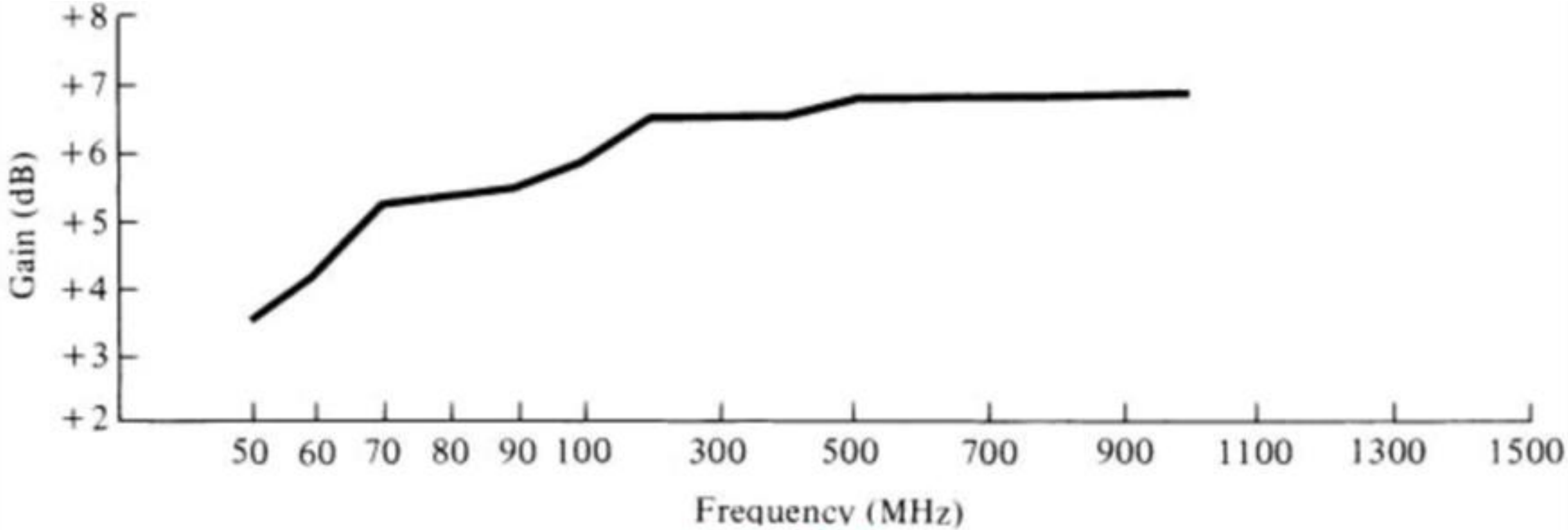
The spacing between the elements is found from:

$$\boxed{d_n = 2\sigma L_n = 2(0.149)L_n = 0.298L_n}$$

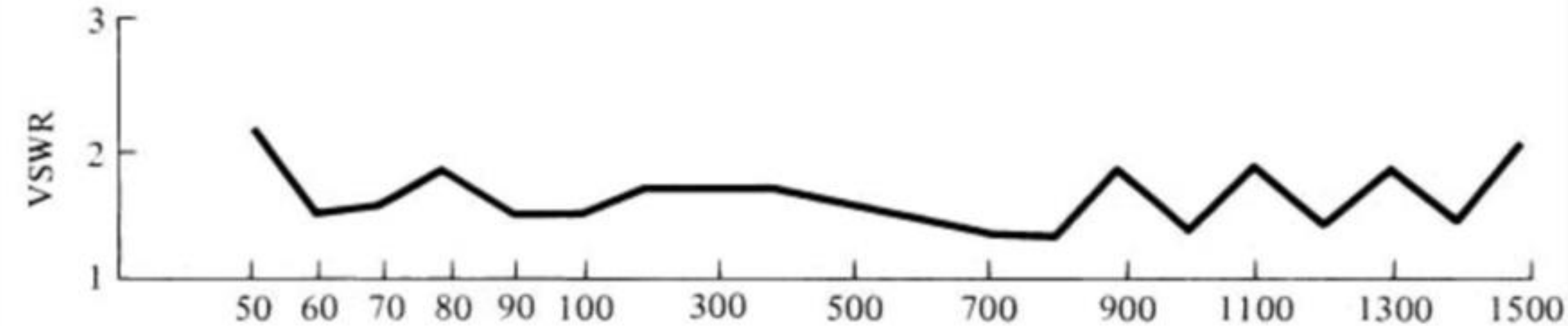
Using dipole lengths, spacing between the elements is calculated as:

d_1 = 0.828 m, d_2 = 0.682 m, d_3 = 0.560 m,
d_4 = 0.459 m, d_5 = 0.378 m, d_6 = 0.310 m,
d_7 = 0.256 m, d_8 = 0.210 m.

Results of LPDA for 54 to 806 MHz

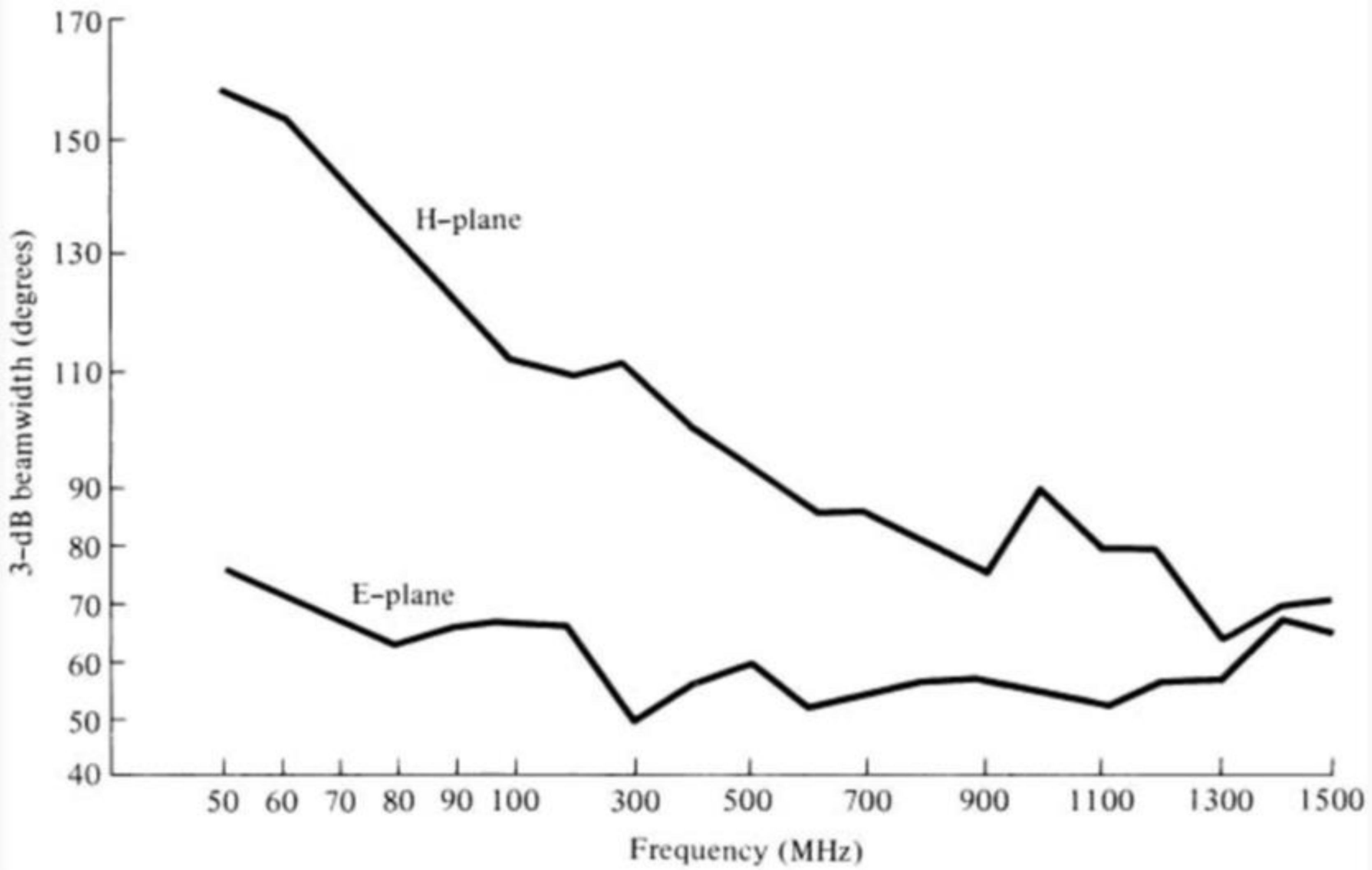


(a) Gain

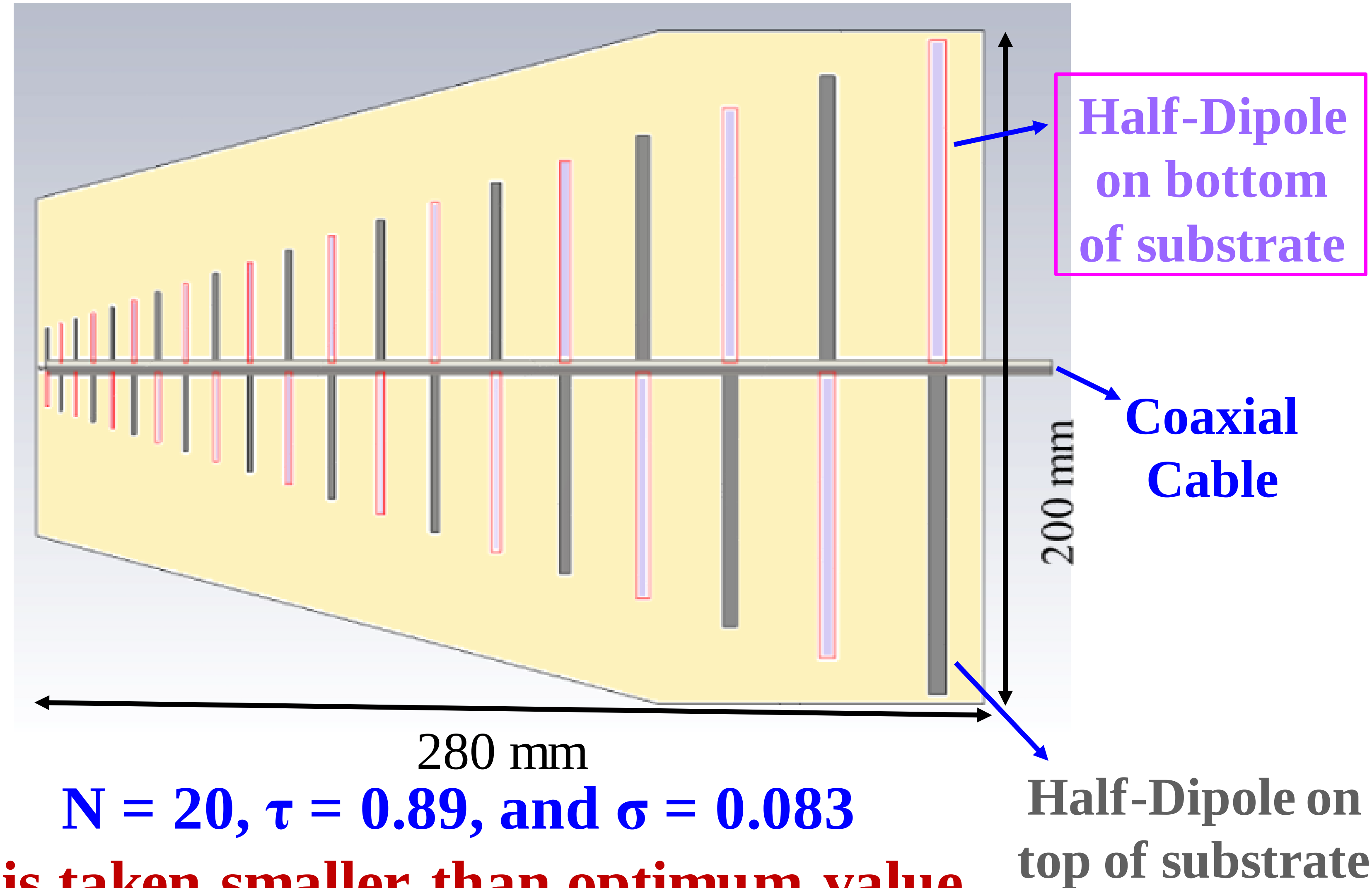


(b) VSWR

HPBW of LPDA for 54 to 806 MHz



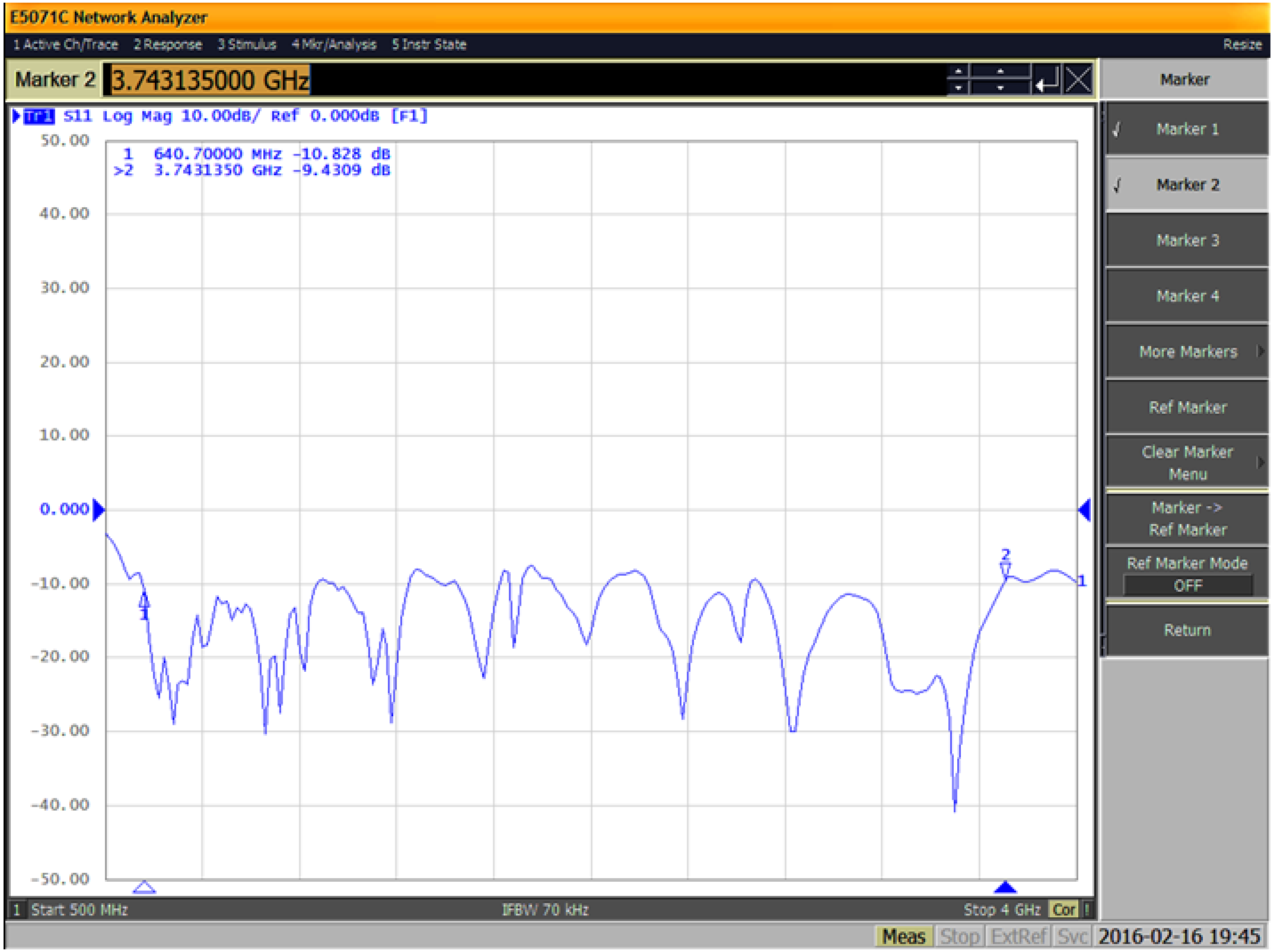
Printed LPDA using Co-axial Balun



N = 20, τ = 0.89, and σ = 0.083

σ is taken smaller than optimum value to reduce overall length of antenna

Measured $|S_{11}|$ of Printed LPDA



For $|S_{11}| \leq$ - 9 dB, Measured BW: 0.64 to 3.74 GHz