

Yagi-Uda and Log-Periodic Antennas

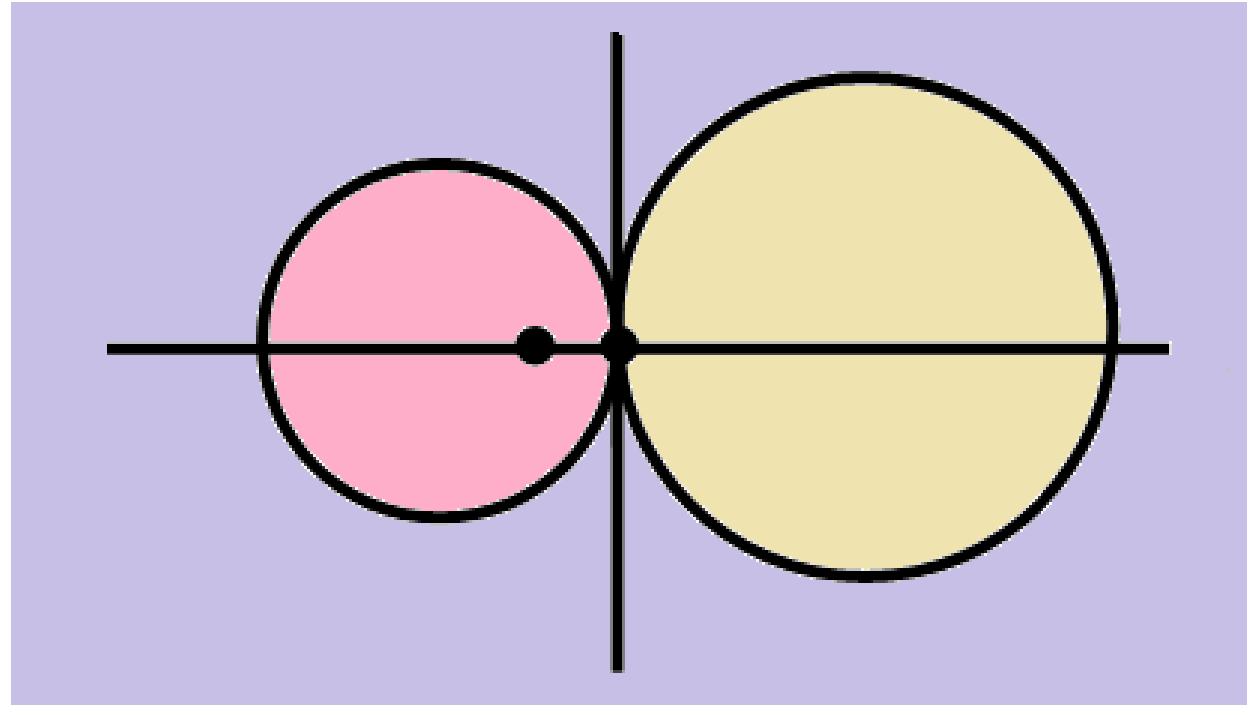
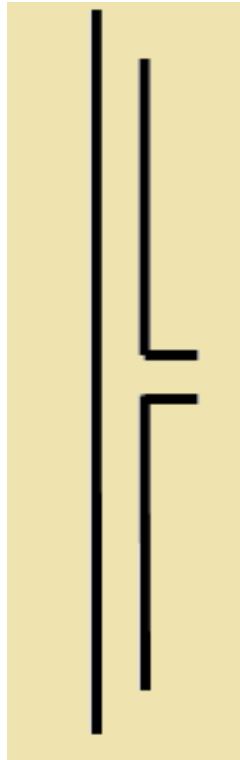
Prof. Girish Kumar

Electrical Engineering Department, IIT Bombay

gkumar@ee.iitb.ac.in

(022) 2576 7436

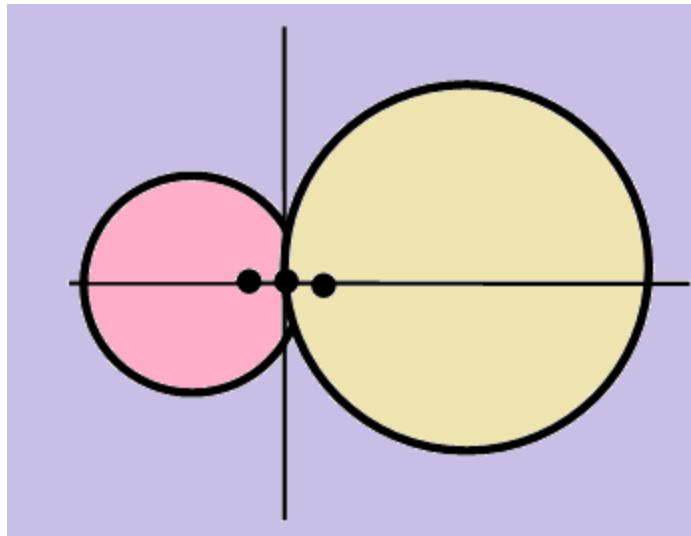
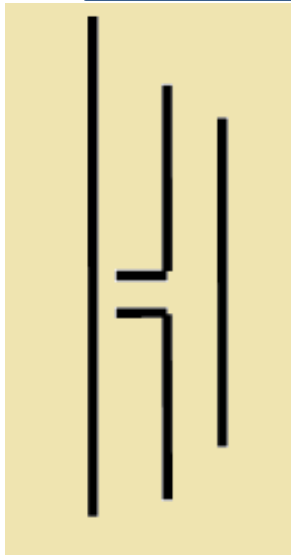
Linear Dipole with a Reflector



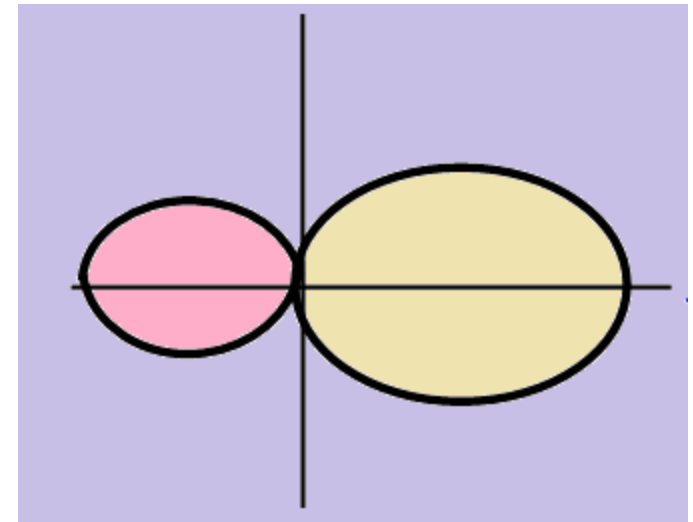
A linear dipole antenna has omni-directional radiation pattern. Gain ≈ 2 dB

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.

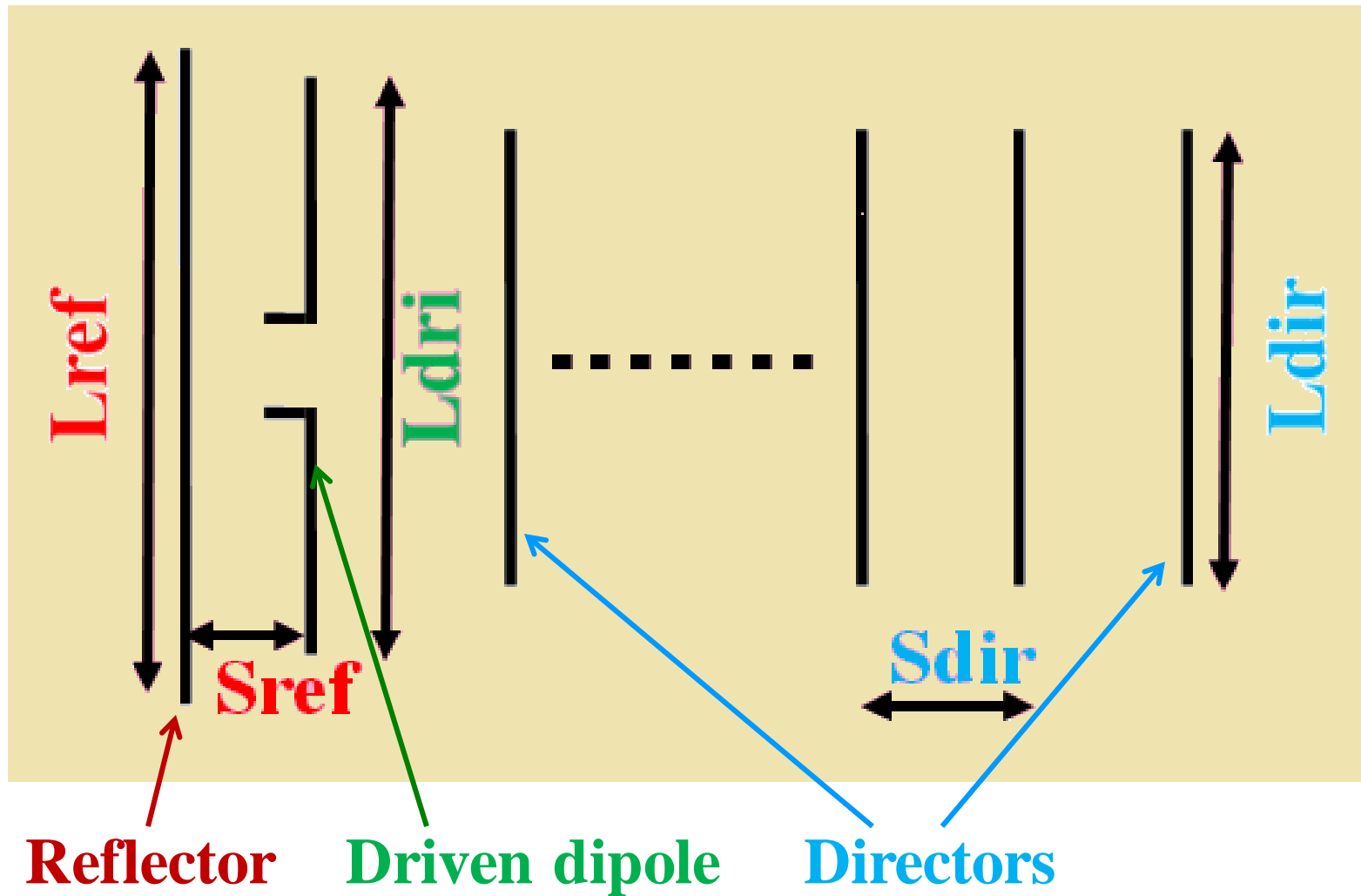
Length of the dipole: $l + d = 0.48\lambda$

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

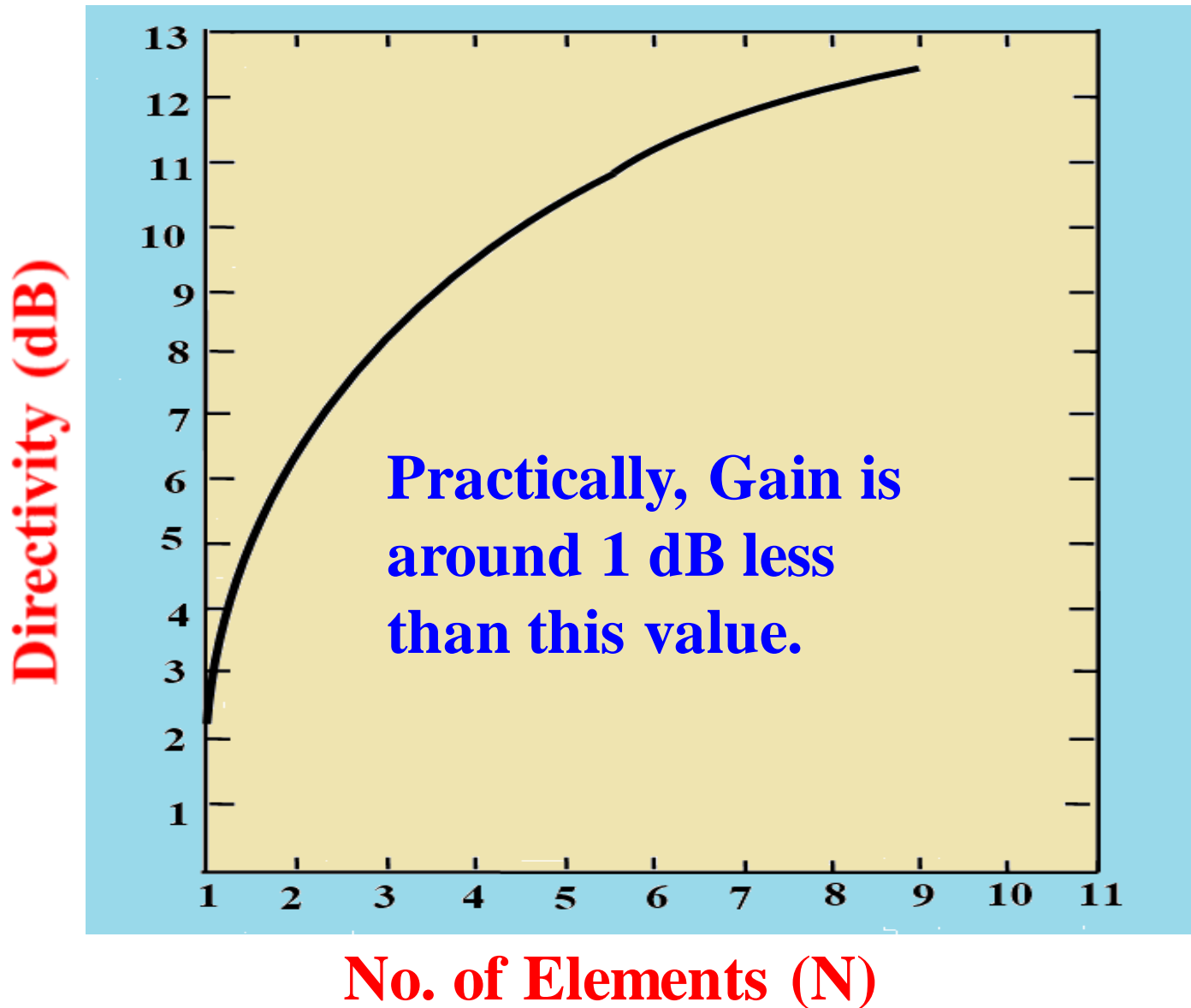
General Yagi-Uda Antenna



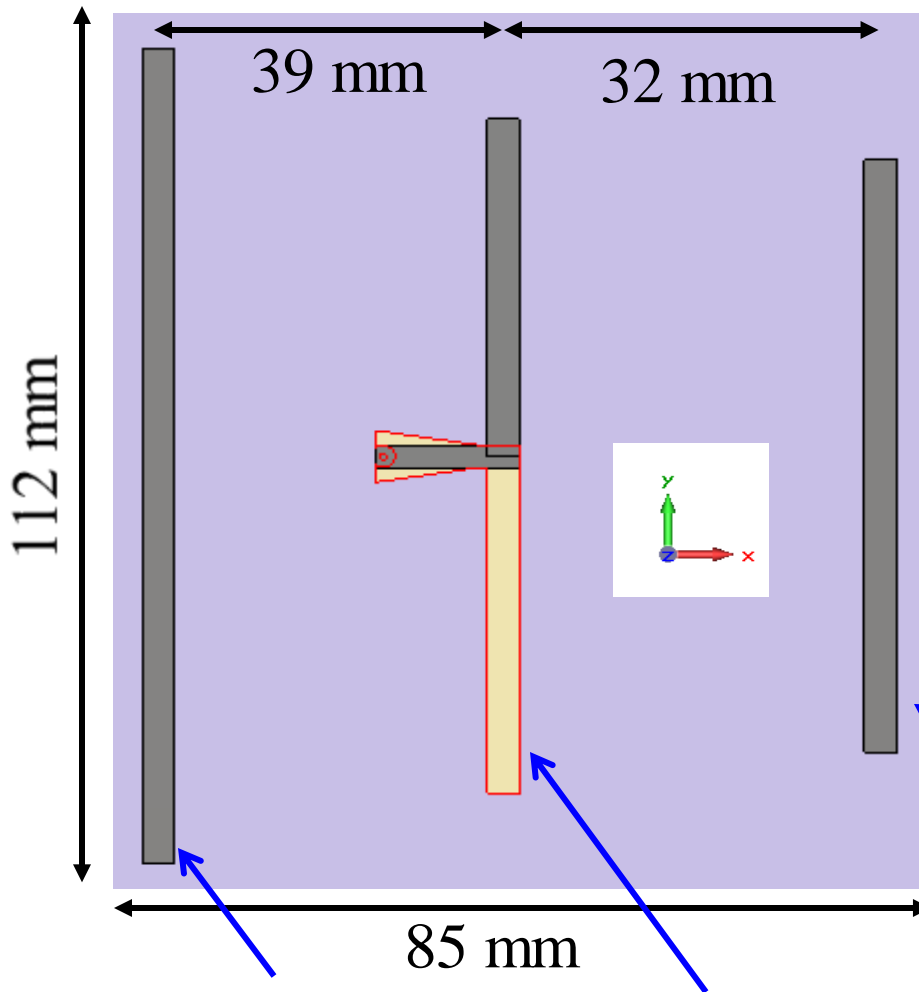
Typical Values of Yagi-Uda Antenna

- 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



Length of Reflector
= 102 mm

Length of Driven
Dipole = 91 mm

Frequency : 1.3 GHz

$\lambda = 230$ mm

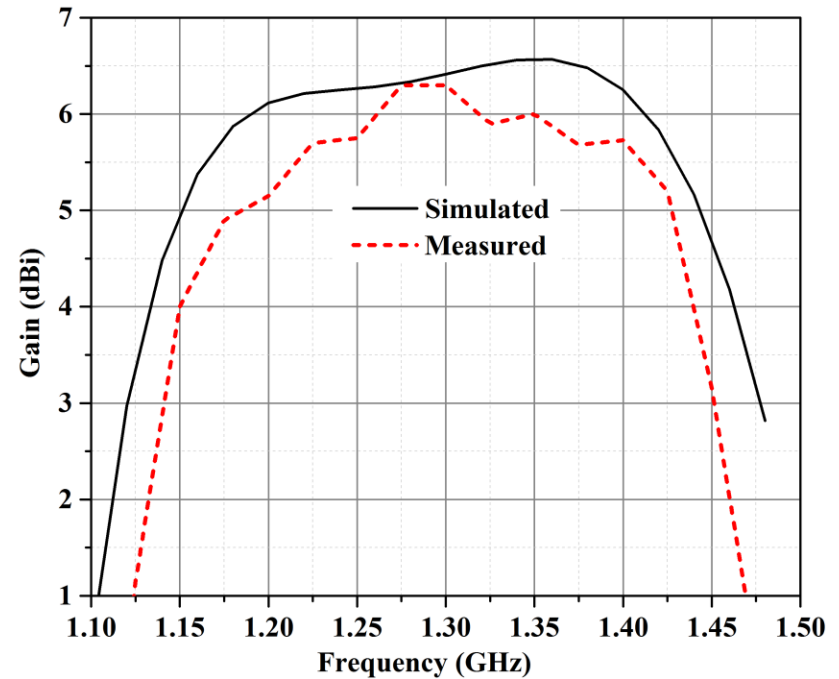
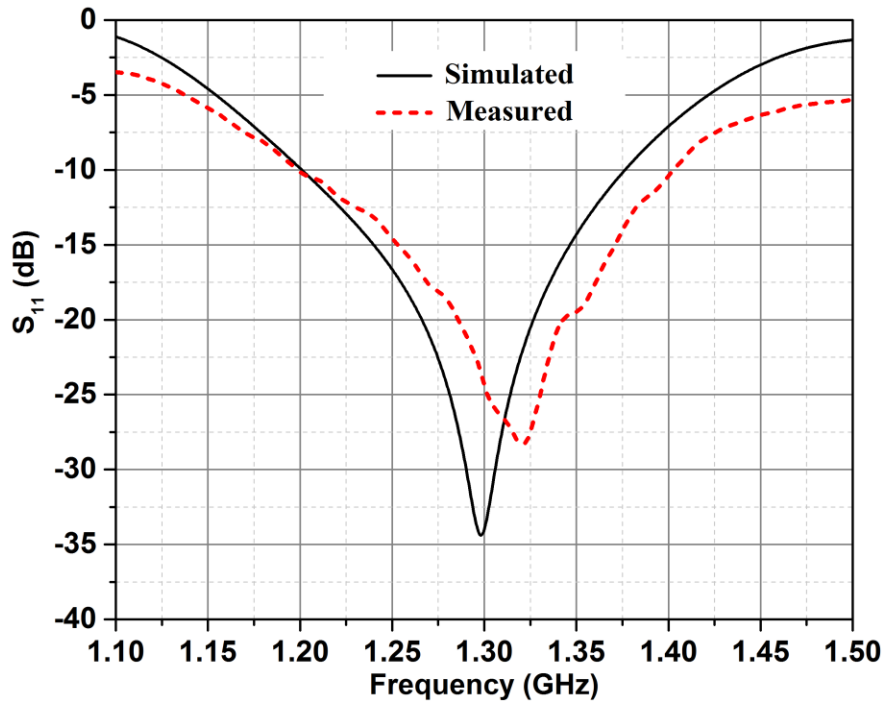
FR 4 Substrate:

$\epsilon_r = 4.4$, $h = 1.6$ mm

$\epsilon_{\text{eff}} \approx 1.3-1.4$ due to
field in air

Length of Director
= 72 mm

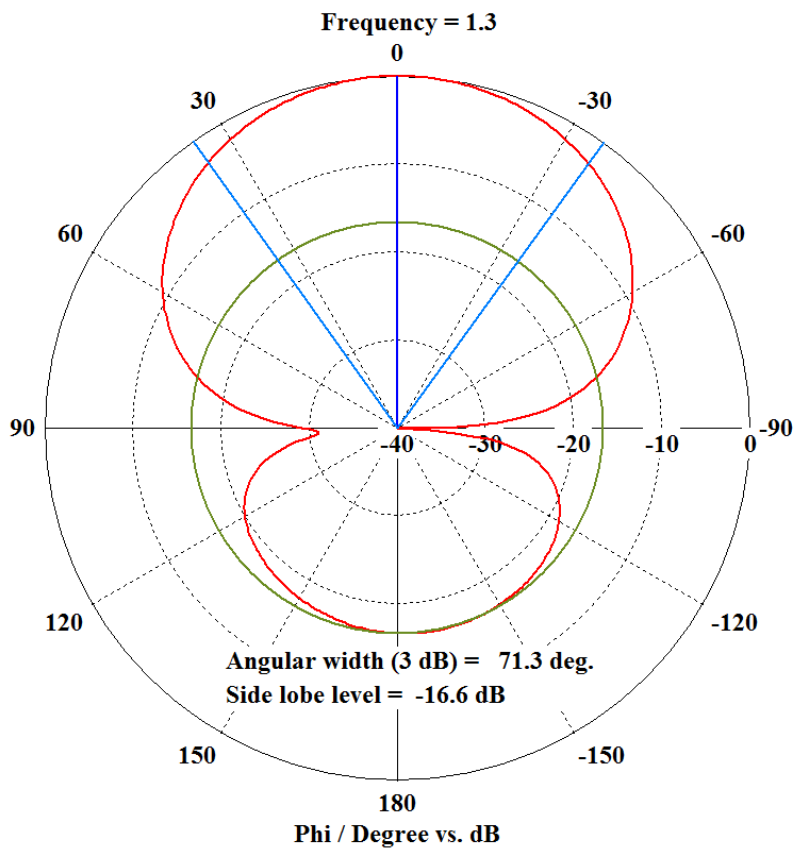
Results of 3-Element Yagi-Uda Antenna



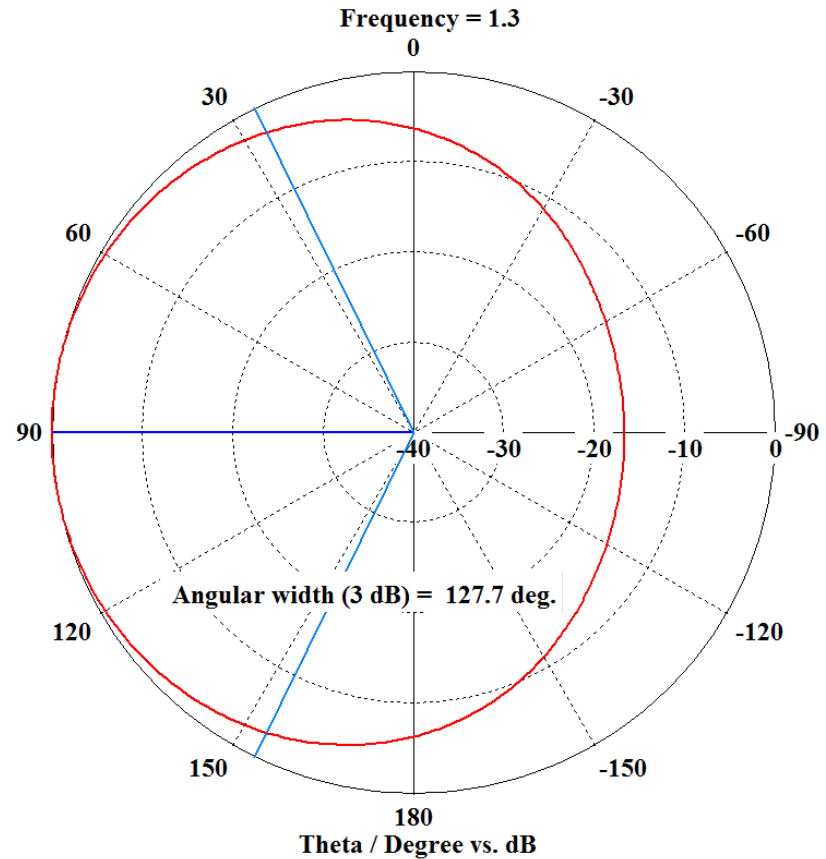
For $|S_{11}| \leq -10$ dB, Measured BW = 15.4%

Measure Peak Gain = 6.3 dB

Radiation Pattern at 1.3 GHz

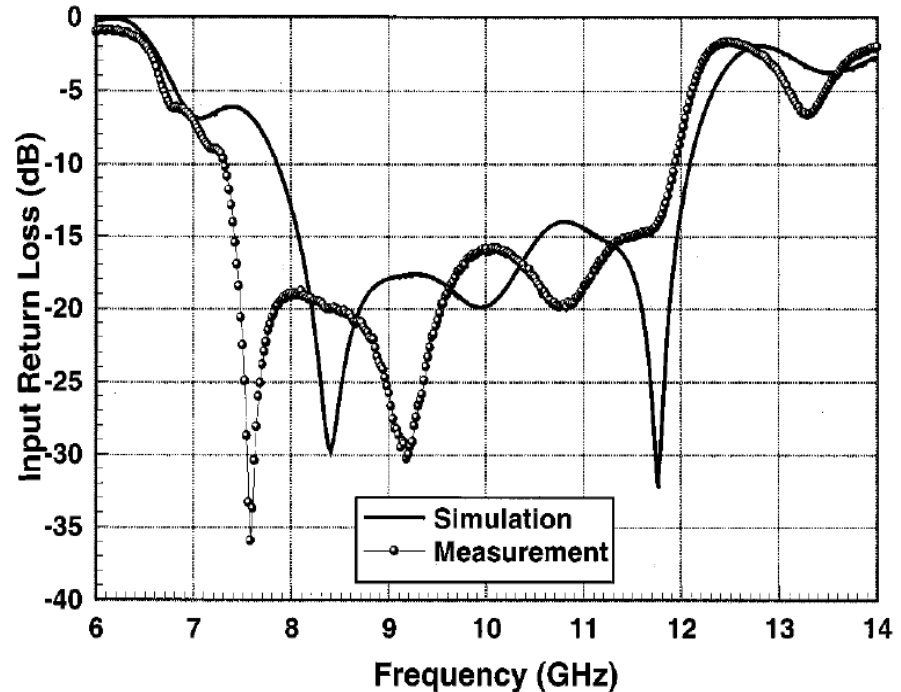
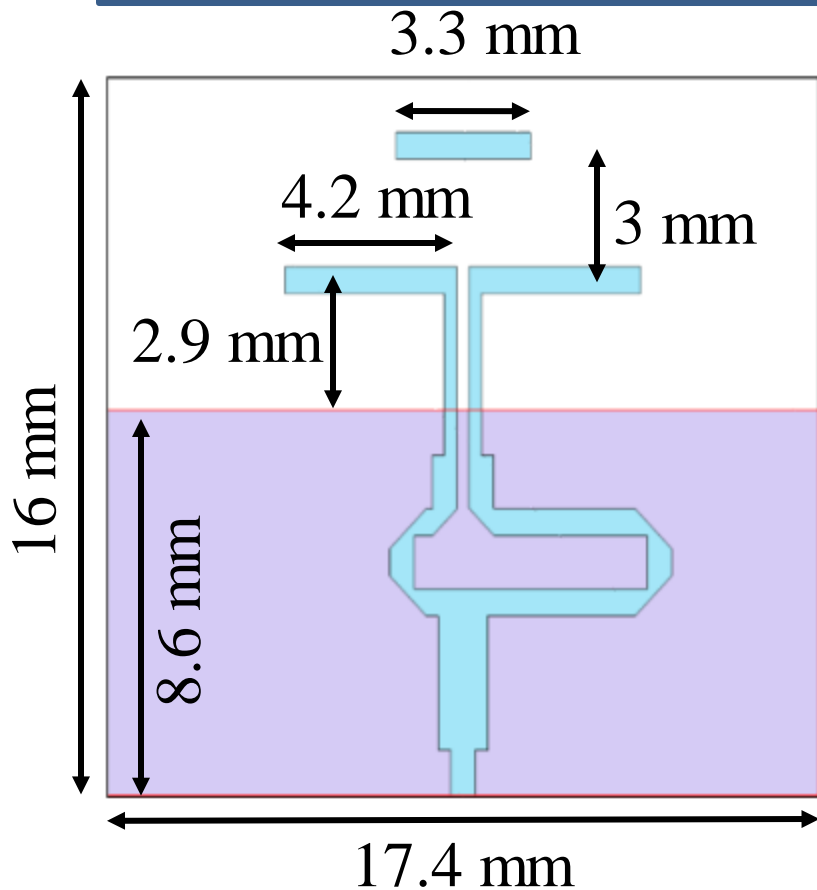


xy Plane – E Plane



xz Plane – H Plane

Broadband Planar Quasi-Yagi Antenna



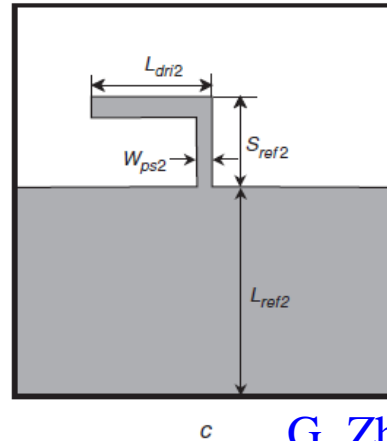
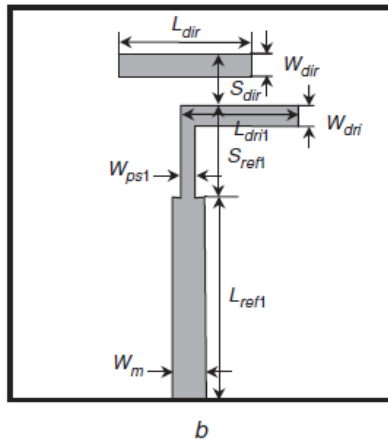
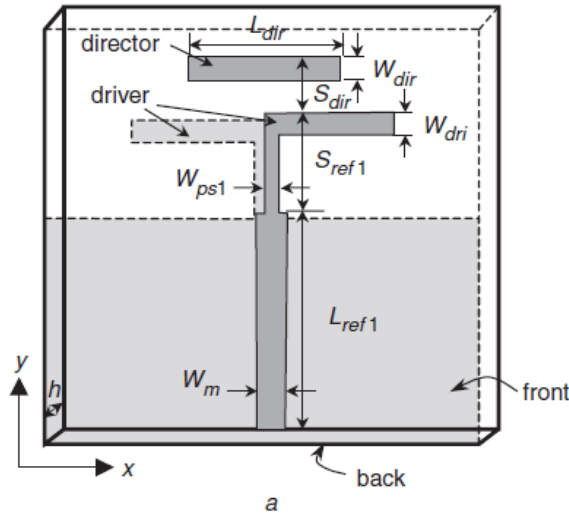
Bandwidth: 48% at X-band
Gain: 3.4 - 5.1 dB

Substrate: $\epsilon_r = 10.2$ 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



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

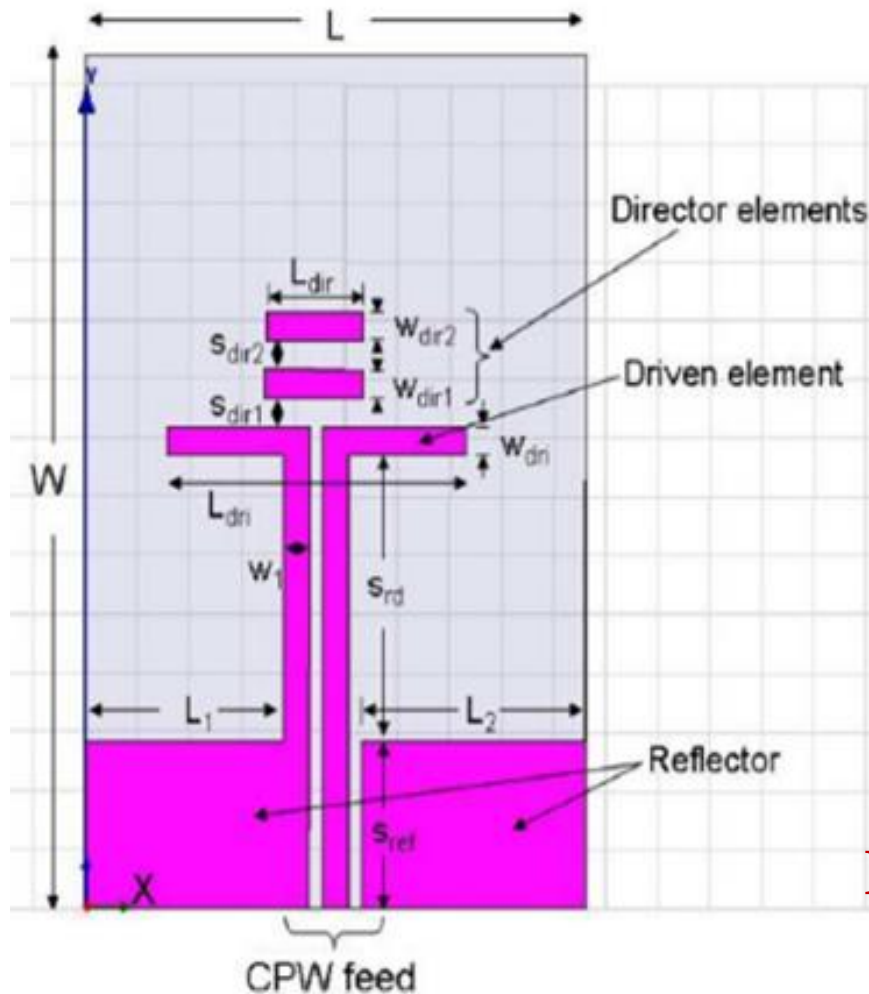
BW = 40% at X-band

Fig. 1 Geometry of modified printed Yagi antenna

a 3D schematic diagram b Top layer
c Bottom layer

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

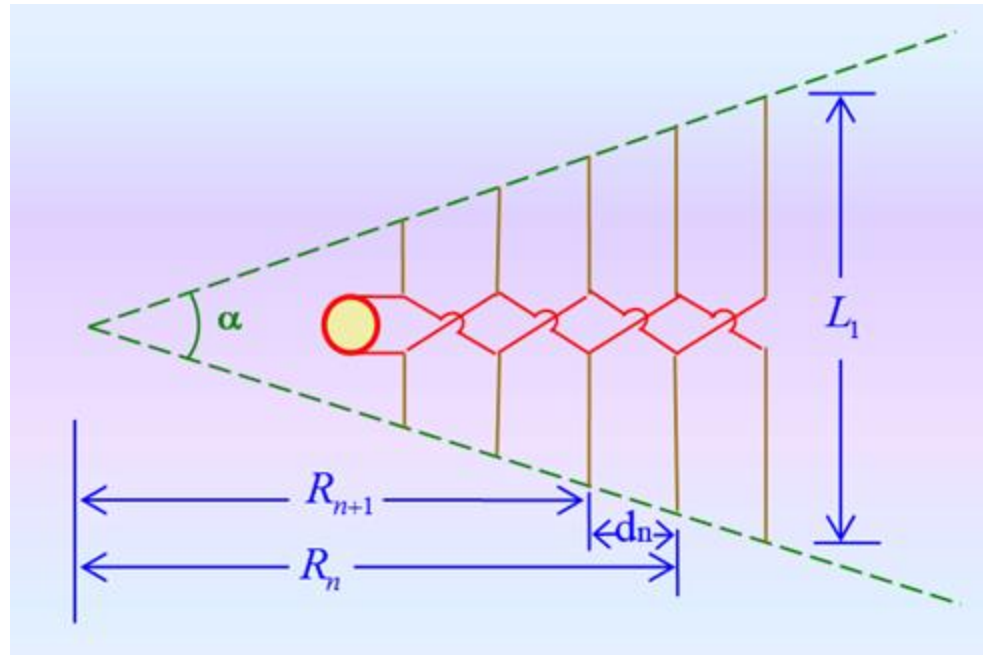


Sref	5.69 mm
Ldir	3.73 mm
L	19.2 mm
W	29 mm
Sdir1=Sdir2	0.96 mm
Wdir1=Wdir2	0.96 mm
L1	8.61 mm
L2	7.61 mm
Srd	9.69 mm
Lri	11.5 mm

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

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



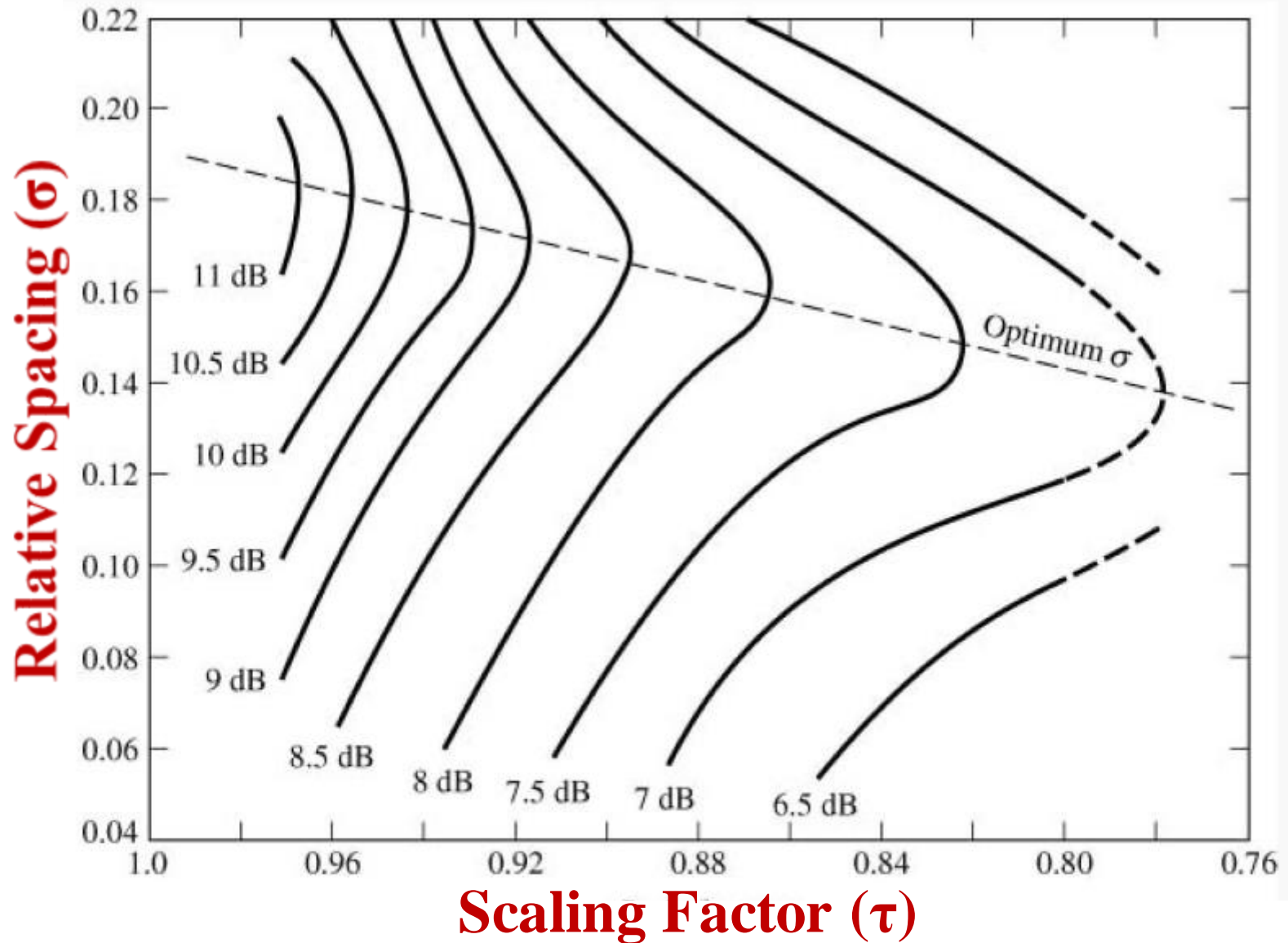
Add one large dipole, which acts as reflector to increase gain at lower frequencies.

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



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,

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

Design of LPDA Antenna (Contd.)

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

$$L_1 = 0.5\lambda_L = 0.5(5.55) = 2.78m$$

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

$$L_U = 0.5\lambda_U = 0.694m$$

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.

$$L_1 = 2.78 \text{ m}, L_2 = 2.29 \text{ m}, L_3 = 1.88 \text{ m},$$

$$L_4 = 1.54 \text{ m}, L_5 = 1.27 \text{ m}, L_6 = 1.04 \text{ m},$$

$$L_7 = 0.858 \text{ m}, L_8 = 0.705 \text{ m}, L_9 = 0.579 \text{ m}.$$

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.)

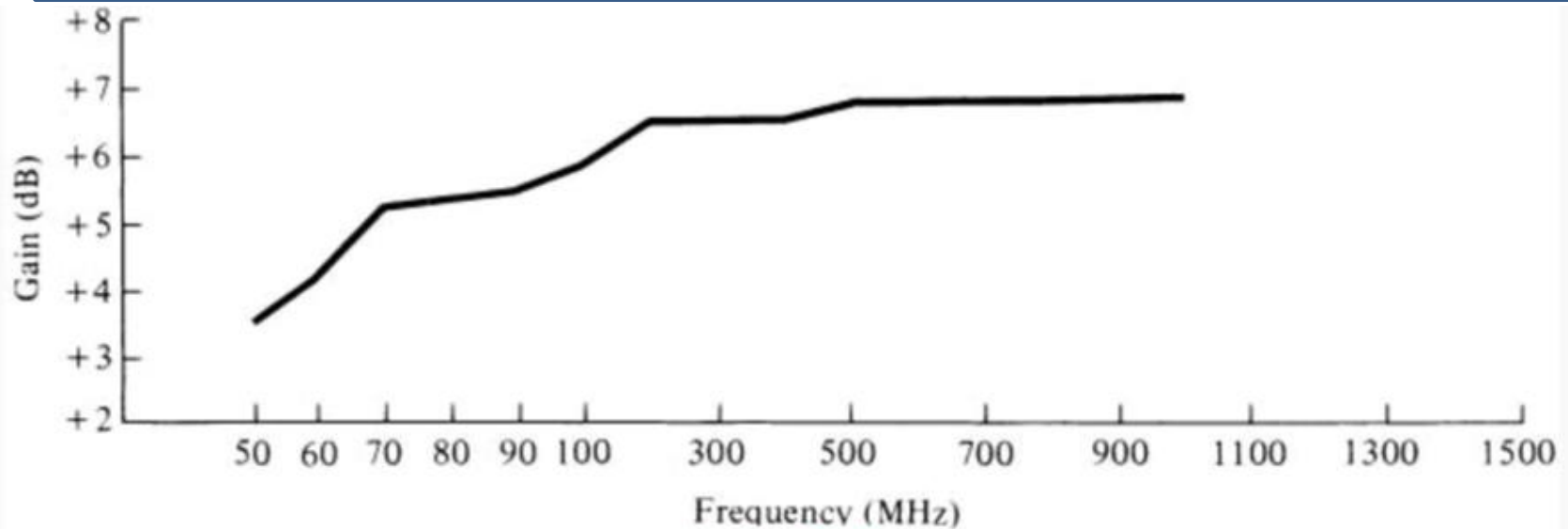
The spacing between the elements is found from:

$$d_n = 2\sigma L_n = 2(0.149)L_n = 0.298L_n$$

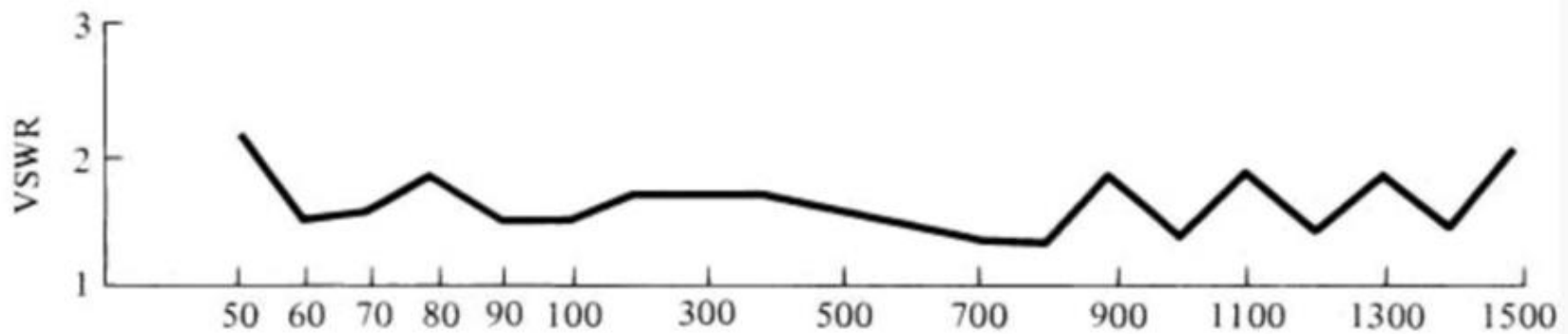
Using dipole lengths, spacing between the elements is calculated as:

$$\begin{aligned}d_1 &= 0.828 \text{ m}, d_2 = 0.682 \text{ m}, d_3 = 0.560 \text{ m}, \\d_4 &= 0.459 \text{ m}, d_5 = 0.378 \text{ m}, d_6 = 0.310 \text{ m}, \\d_7 &= 0.256 \text{ m}, d_8 = 0.210 \text{ m}.\end{aligned}$$

Results of LPDA for 54 to 806 MHz

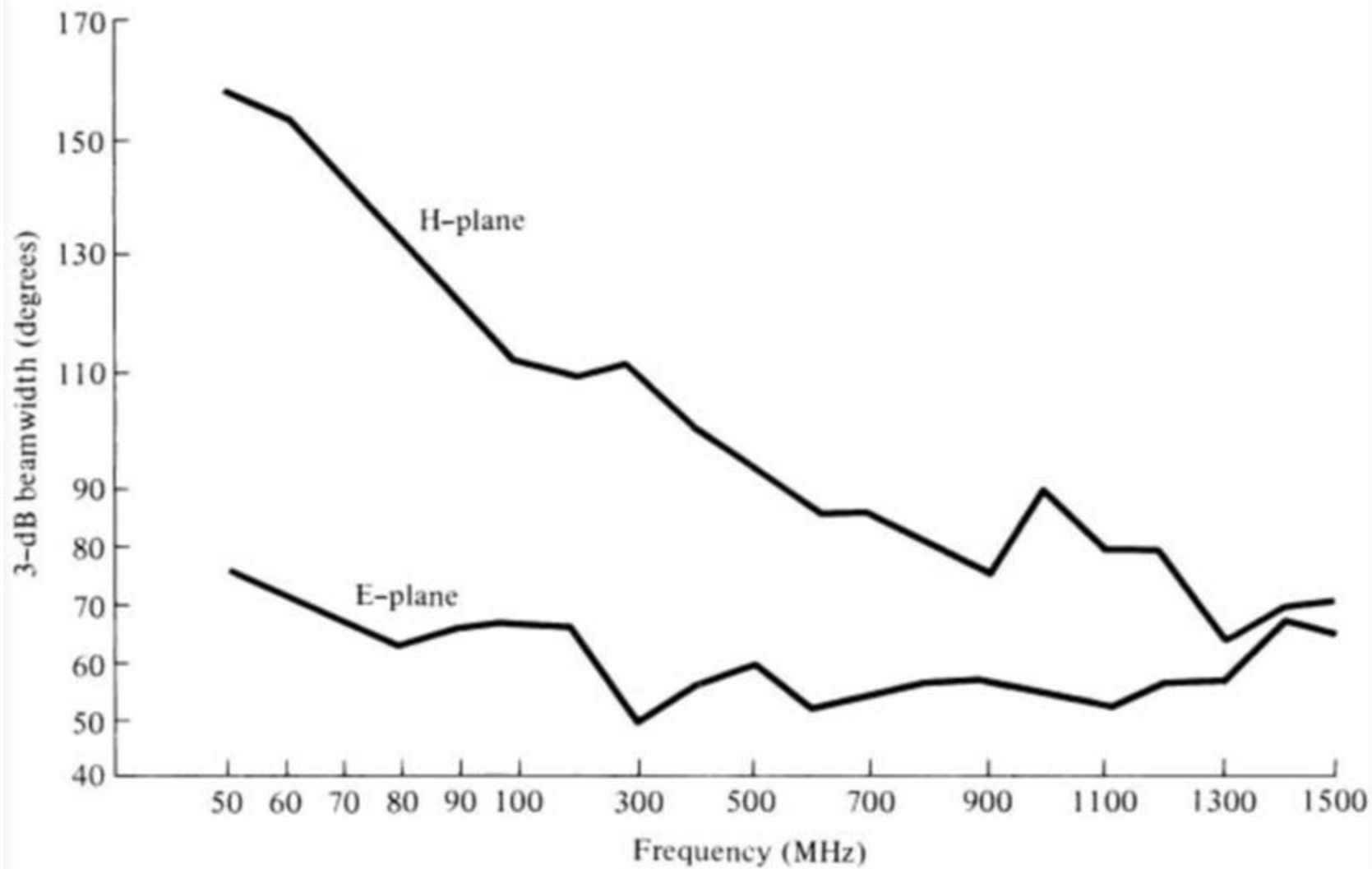


(a) Gain

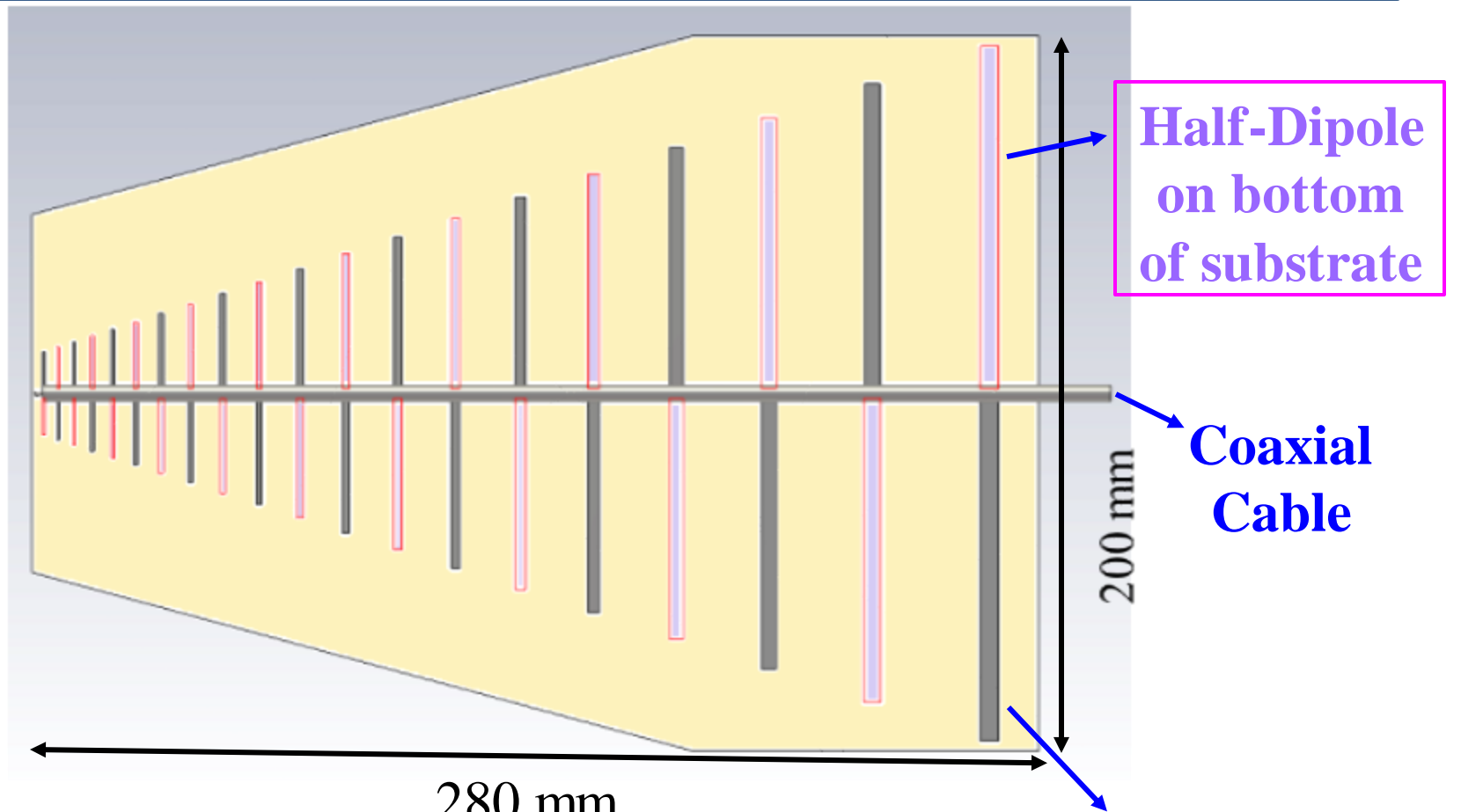


(b) VSWR

HPBW of LPDA for 54 to 806 MHz



Printed LPDA using Co-axial Balun



Half-Dipole
on bottom
of substrate

Coaxial
Cable

Half-Dipole on
top of substrate

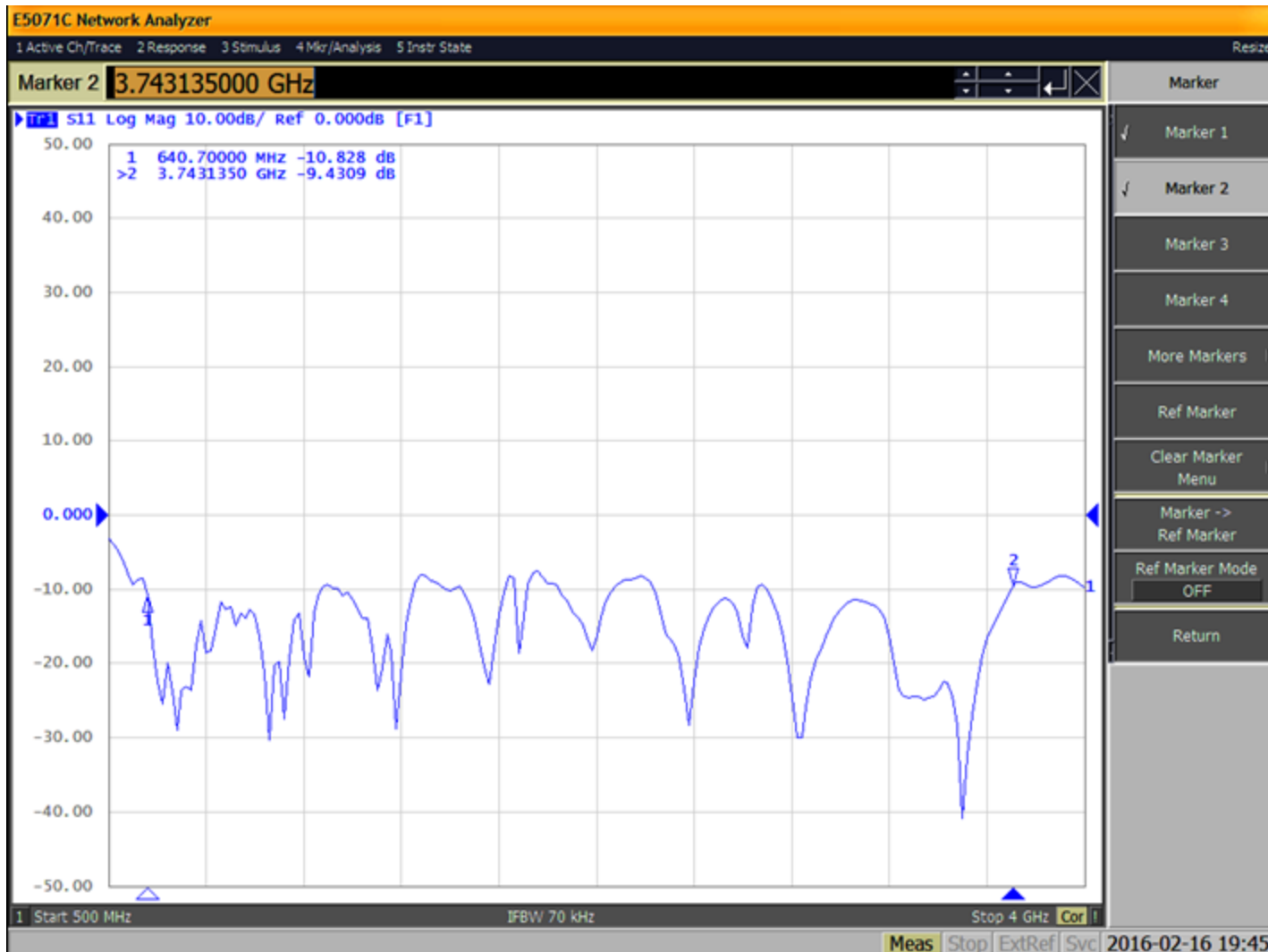
280 mm

200 mm

$N = 20$, $\tau = 0.89$, and $\sigma = 0.083$

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