

Laboratory Assignment No.2
The microstrip patch and Yagi-Uda antenna

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Chapter 1

Microstrip Patch Antenna

This type of antenna is used where it's low cost, weight, size and ease of installation is an important property. The disadvantages of microstrip antennas are their low efficiency, low power, poor polarization purity and very narrow bandwidth.

1.1 Questions

1. For a rectangular patch antenna, explain the acronym TM_{010}^x ?

TM stands for Transverse Magnetic, the x is the direction of the current. The three numbers represent the number of half-cycle field variations (number of zeros) along the x, y, z directions. In this case we have one zero in the y direction.

2. For a circular patch antenna, explain the acronym TM_{110}^z

TM as before, here z is the direction of the current. This mode is the first and dominant mode.

3. Explain at least two methods for analyzing microstrip antennas.

The most popular models are the transmission-line model, cavity and full-wave. The transmission-line model is the easiest, but it yields the least accurate results. Because of fringing effect an effective dielectric constant $\epsilon_{r,eff}$ is introduced ($1 < \epsilon_{r,eff} < \epsilon_r$). This constant is a function of frequency. At high frequency it approaches ϵ_r .

Design procedure:

- 1.

$$W = \frac{c_0}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

2. Determine $\epsilon_{r,eff}$

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2}$$

3. Once W is found, determine ΔL

$$\Delta L = 0.412h \frac{(\epsilon_{r,eff} + 0.3) \left(\frac{W}{h} + 0.264\right)}{(\epsilon_{r,eff} - 0.258) \left(\frac{W}{h} + 0.8\right)}$$

4. Now we can find the actual length

$$L = \frac{c_0}{2f_r \sqrt{\epsilon_{r,eff}}} - 2\Delta L$$

The cavity model is more accurate, but also more complex. The fields within the dielectric substrate can be found by treat that region as a cavity bounded by electric conductors above and below and by magnetic walls along the perimeter of the patch. When we apply energy to the patch a charge distrobution is established. The movement of this charges correspond to current densities at the top and the bottom of the patch. Because the height-to-width ratio is very small the charge consentation on the bottom of the patch dominates.

4. Explain the meaning of the fringing effect.

Because the dimensions of the patch are finite along the length and width, the fields at the edges undergo fringing. Fringing influnces the resonant frequency of the antenna. It is a function of the length of the patch and the height of the substrate and also ϵ_r of the substrate.

5. Using the cavity model, explain how to calculate the total electric field E_ϕ for a rectangular microstrip antenna, which dominating radiation is in the TM_{010}^x mode?

To calculate the field from the microstrip patch which dominating radiation is in the TM_{010}^x mode we represent the antenna by two radiating slots along the length of the patch. Then we get the total field by sum the fields from the two slots which are identical, this is accomplished by using an array factor. The total field from the two slots is

$$E_\phi^t = j \frac{k_0 h W E_0 e^{-jk_0 r}}{\pi r} \left\{ \sin \theta \frac{\sin(X)}{X} \frac{\sin(Z)}{Z} \right\} \times \cos \left(\frac{k_0 h}{2} \sin \theta \sin \phi \right) \quad (1.1)$$

where

$$X = \frac{k_0 h}{2} \sin \theta \cos \phi \quad (1.2)$$

$$Z = \frac{k_0 W}{2} \cos \theta \quad (1.3)$$

6. Using the cavity model, explain how to calculate the total electric field E_ϕ for a rectangular microstrip antenna, which dominating radiation is in the TM_{110}^z mode?

To calculate the fields from a circular patch we use a Equivalence Principle

whereby the circumferential wall of the cavity is replaced by an equivalent magnetic current density. Then we can treat the antenna as a circular loop and the fields can be written as

$$E_r = 0 \quad (1.4)$$

$$E_\theta = -j \frac{k_0 a_e V_0 e^{-jk_0 r}}{2r} \{\cos \phi J'_{02}\} \quad (1.5)$$

$$E_\phi = j \frac{k_0 a_e V_0 e^{-jk_0 r}}{2r} \{\cos \theta \sin \phi J_{02}\} \quad (1.6)$$

$$J'_{02} = J_0(k_0 a_e \sin \theta) - J_2(k_0 a_e \sin \theta) \quad (1.7)$$

$$J_{02} = J_0(k_0 a_e \sin \theta) + J_2(k_0 a_e \sin \theta) \quad (1.8)$$

$$(1.9)$$

where a_e is the effective radius given below.

7. Explain how to calculate corrections to the fringing effect for the TM_{110}^z mode?

For a circular patch we correct for the fringing affect by use of a effective radius a_e

$$a_e = a \left\{ 1 + \frac{2h}{\pi a \epsilon_r} \left[\ln \left(\frac{\pi a}{2h} \right) + 1.7726 \right] \right\}^{1/2}$$

1.2 Matlab Plots

Table 1.1: Antenna parameters

Parameter	Value
Physical widtht	1.1859 cm
Effective length	1.0683 cm
physical length	0.9061 cm
E-plane HPBW	44.5000°
H-plane HPBW	38.4000°
Directivity, D_0	5.4136
Directivity, D_0	7.3349 dB
resonant input resistance at feedpoint ($y = 0$)	228.4108Ω
resonant input resistance at feedpoint ($y = y_0$)	50.0053Ω

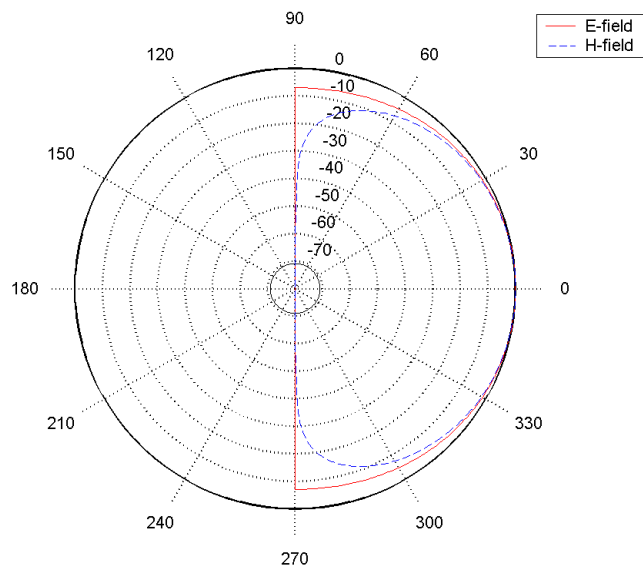


Figure 1.1: E- and H-plane patterns for a rectangular microstrip patch antenna with height $h = 0.1588$ cm, relative dielectric constant $\epsilon_r = 2.2$ and resonant frequency $f = 10$ GHz

Chapter 2

Yagi-Uda antenna

2.1 Questions

1. What is the main elements of this antenna?

The main elements is the fed/driven element, the directors and the reflector. The driven element is energized directly by a feed transmissionline. The directors act as parasitic radiators whose currents are induced by mutual coupling. The usual number of directors is 6-12, the more directors the higher directivity. The reflector spacing and size has negligible effects on the forward gain and large effect on the backward gain.

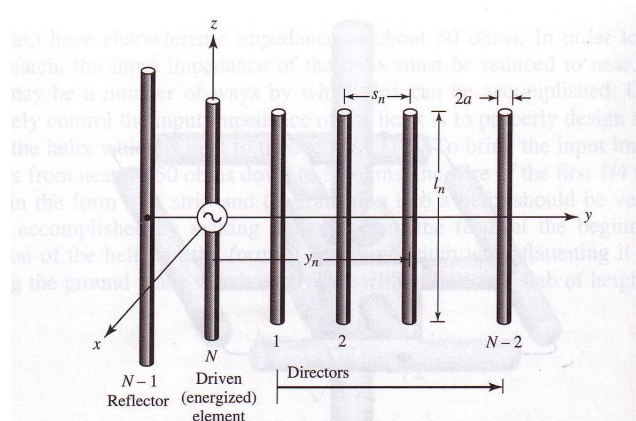


Figure 2.1: The Yagi-Uda antenna

2.2 Results

In our design we decided to optimise the front-to-back ratio of the antenna. First we used values we thought were good, then we changed the separation between the directors and the front-to-back ratio got better.

Table 2.1: Antenna parameters

Parameter	Before optimisation	After optimisation
number of elements	15	15
number of modes per element	10	10
length of directors	0.4λ	0.4λ
length of reflector	0.6λ	0.6λ
length of feeder	0.47λ	0.47λ
separation between directors	0.3λ	0.26λ
separation feeder-reflector	0.3λ	0.3λ
radius of elements	0.004λ	0.004λ
3-dB beamwidth E-plane	27.56°	28.57°
3-dB beamwidth H-plane	28.58°	29.74°
Front-to-back ratio E-plane	20.5017 dB	24.2099 dB
Front-to-back ratio H-plane	20.4833 dB	24.2043 dB
Directivity, D_0	13.287 dB	13.043 dB

2.2.1 plot

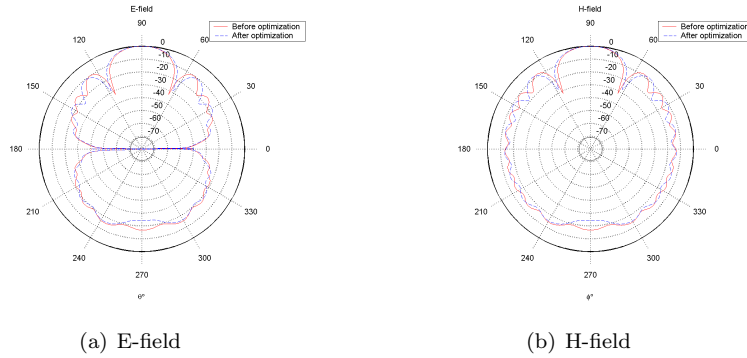


Figure 2.2: E- and H-fields of a 15 element Yagi-Uda array before and after optimization