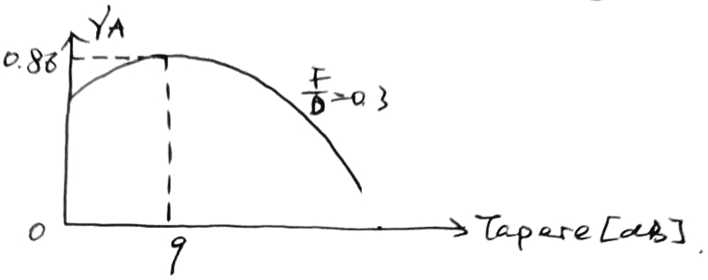
REMS Assignment 5 TONG LIN S2876497.

Problem 5.1

In order to obtain the optimum value of the diameter (D), the highes paraboloid effeciency should be selected, as 0.86, according to the figure, with the case of $\frac{F}{D}=0.3$.



Considering the additional reduction of the aperture efficiency of 1dB, the final efficiency is,

$$\gamma = \gamma_A|_{dB} - 1dB = 10\log_{10}0.86 - 1 \simeq -1.66\ dB.$$

The diameter D can be than obtained with the function of gain, which is,

$$G = \frac{4\pi}{\lambda^2}\cdot\gamma\cdot A_{geo}$$
$$= \frac{4\pi}{\lambda^2}\cdot\gamma\cdot\pi\left(\frac{D}{2}\right)^2$$

The value of gain can be analyzed as follows.
Starting with the receiving power,

$$P_R = P_T\cdot\frac{G_R G_T}{\left(\frac{4\pi R}{\lambda}\right)^2}\left(1-|\Gamma_R|^2\right)\left(1-|\Gamma_T|^2\right)\cdot|\hat{P}_r\cdot\hat{P}_T^*|^2$$

where in the condition of matched antenna, $\Gamma_R=0$, $\Gamma_T=0$, also with the same polarization of transmitter and the receiver, $|\hat{P}_R\cdot\hat{P}_T^*|=1$.
The expression can then written in the unit of dB as,

$$P_R[dB] = P_T[dB] + G_R[dB] + G_T[dB] - 10\log_{10}\left(\frac{4\pi R}{\lambda}\right)^2$$

where in the expression, the known values are,
$P_R \geq -70dB$, $P_T = 10kW = 40dB$, $G_R = 25dB$, $R = 36000km$, $f = 18\ GHz$, $10\log_{10}\left(\frac{4\pi R}{\lambda}\right)^2 \simeq 208.67\ dB$.

Therefore,

$$G_T = P_R - P_T - G_R + 10\log_{10}\left(\frac{4\pi R}{\lambda}\right)^2$$
$$\geq -70 - 40 - 25 + 208.67$$
$$= 73.67\ dB.$$

Then, $D \simeq 31m$.

Problem 5.2

The diameter of the reflector can be obtained with the value of gain and aperture efficiency, with the expression,

$$G = \frac{4\pi}{\lambda^2} \cdot \eta_A \cdot A_{geo}$$

where $\lambda = \frac{c}{f} = \frac{3\times10^8}{2.54\times10^9} = 0.12\,m$

and $A_{geo} = \pi \left(\frac{D}{2}\right)^2$.

The gain G can be calculated using the expression,

$$G = \frac{\frac{dP}{d\Sigma}}{\left(\frac{dP}{d\Sigma}\right)_{iso}}$$

where $\frac{dP}{d\Sigma} = \frac{|E|^2}{Z_0} = \frac{(150\times10^{-3}\,V/m)^2}{120\pi\,\Omega} \simeq 5.97\times10^{-5}$

$$\left(\frac{dP}{d\Sigma}\right)_{iso} = \frac{P_{feed}}{4\pi R^2} = \frac{55}{4\pi(15\times10^3)^2} \simeq 1.946\times10^{-8}$$

$$G = \frac{5.97\times10^{-5}}{1.95\times10^{-8}} \simeq 3062$$

Assuming that the fields are symmetrical,

$$HPBW = \sqrt{\frac{3\times10^4}{G}} \simeq 3.13°$$

For the first side-lobe,

$$\frac{\theta_{1L}}{HPBW} = 1.5 \quad , \quad \theta_{1L} = 3.13° \times 1.5 \simeq 4.70°$$

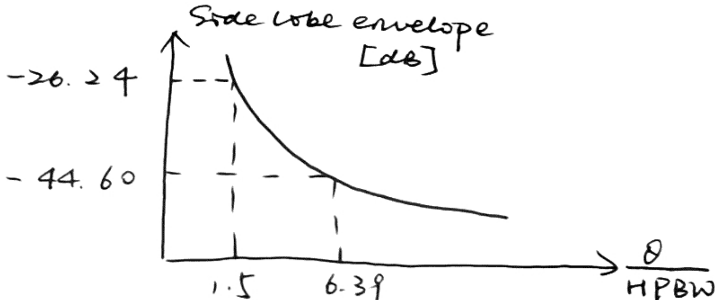
$$\left.\frac{g_{SLL}(\theta_{1L})}{G}\right|_{dB} = (-20.6 - 1.2\times4.70°) = -26.24\,dB$$

For the maximum angle,

$$\frac{\theta_{max}}{HPBW} = \frac{20°}{3.13°} \simeq 6.39$$

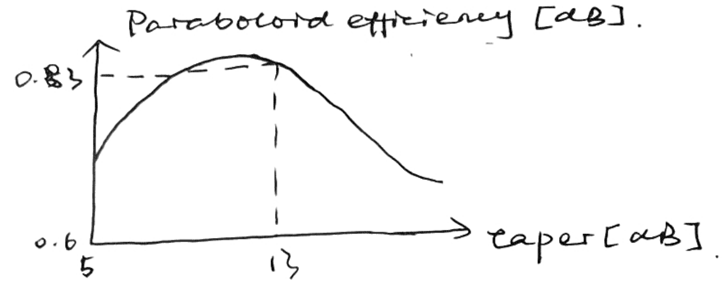
$$\left.\frac{g_{SLL}(\theta_{max})}{G}\right|_{dB} = (-20.6 - 1.2\times20°) = -44.6\,dB$$

Checking the figure with 'Side lobes envelope vs. θ/HPBW',



$t \simeq -13\,dB$.

With $\tau = -13\,dB$, $\frac{F}{D} = 0.4$, according to the figure, $\nu_A = 0.83$.



Considering the reduction of 1 dB of the aperture efficiency,

$$\nu = \nu_A|_{dB} - 1$$
$$= 10\log_{10} 0.83 - 1 \simeq -1.8092\,dB.$$

Therefore,

$$D = \sqrt{\frac{G \cdot \lambda^2}{4\pi^2 \cdot \nu}} \cdot 2 \simeq 2.6\,m.$$

The field intensity can be expressed as the ratio between the field along the maximum angle $\theta_{max} = 20°$ and the maximum field along $\theta = 0$,

$$\tau_0 = \frac{|E(\theta_{max} = 20°, \varphi)|}{|E(\theta_0 = 0°, \varphi)|}$$

As $\underline{E}(\theta, \varphi) = V_0 \cdot \frac{e^{-jkr}}{r} \cdot F(\theta, \varphi) \cdot \hat{p}(\theta, \varphi)$.

$$\tau_0 = \frac{|F(\theta_{max}, \varphi)|}{|F(\theta_0, \varphi)|} \cdot \frac{r_0}{r_{\theta max}}$$
$$= \cos^2\left(\frac{\theta_{max}}{2}\right) \frac{|F(\theta_{max}, \varphi)|}{|F(\theta_0, \varphi)|}$$
$$= \alpha_{space} + \alpha_{feed}.$$

where $\alpha_{space} = \cos^2\left(\frac{\theta_m}{2}\right)$.

$\theta_m = 2\arctan\left(\frac{1}{4} \cdot \frac{D}{f}\right)$, thus $\alpha_{space} = 0.99°$
$= 56.73\,rad.$
$= -0.04\,dB$

$$\alpha_{feed} = \tau_0 - \alpha_{space}$$
$$= (-13\,dB) - (-0.04\,dB) = -13.04\,dB.$$