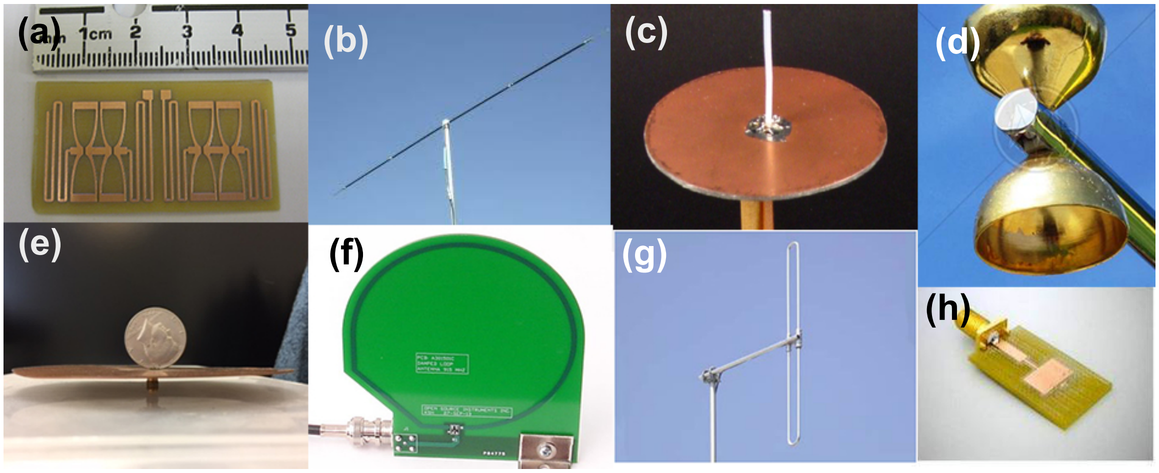
ECE 4370: Antenna Engineering
Solutions to TEST 1 (Fall 2017)

1. **Antenna Recognition:**



1.	Half-Wave Dipole	(b)	5.	Meandered Dipole	(a)
2.	$\frac{\lambda}{4}$-Monopole	(c)	6.	Biconical Antenna	(d)
3.	Patch Antenna	(h)	7.	Loop Antenna	(f)
4.	Folded Dipole	(g)	8.	Broadband Monopole	(e)

2. **Directivity:** Directivity must average to 1 over 4π steradians. If an antenna radiates into an octant with directivity D_0 and radiates into the remaining 7 octants with directivity 0, then D_0 must equal 8 in the linear scale (9 dBi).

3. **Shortened Dipole:**

   (a) Neglecting the coupling between meandered horizontal segments, this resonating antenna should be $\lambda/2$ in length when straightened.

   (b) Start with the vector magnetic potential, making the same phase approximation for the electrically short dipole:

$$\tilde{A}_z(r,\theta,\phi) = \frac{\mu}{4\pi r}\exp(-jkr)\int_{-\frac{L}{2}}^{+\frac{L}{2}} I\cos\frac{z'\pi}{L}\exp(\underbrace{+jkz'\cos\theta}_{\approx 0})\,dz' = \frac{\mu I L}{2\pi^2 r}\exp(-jkr)$$

From this we arrive at the far-field electric and magnetic field solutions:

$$\tilde{\vec{\mathrm{H}}}(r,\phi,\theta) \approx \frac{jkIL\sin\theta}{2\pi^2 r}\exp(-jkr)\,\hat{\phi} \qquad \tilde{\vec{\mathrm{E}}}(r,\phi,\theta) \approx \frac{jk\eta IL\sin\theta}{2\pi^2 r}\exp(-jkr)\,\hat{\theta}$$

(c) 90 degrees (identical to the Hertzian and electrically short dipoles)

(d) We neet to calculate total radiated power for this:

$$
\begin{aligned}
P_T &= \int_0^{2\pi}\int_0^{\pi} \overbrace{\frac{1}{2}\tilde{\vec{\mathrm{E}}} \times \tilde{\vec{\mathrm{H}}}^*}^{\vec{\mathrm{S}}_{\mathrm{av}}} \cdot r^2 \sin\theta \, d\theta \, d\phi \, \hat{\mathrm{r}} \\
&= \int_0^{2\pi}\int_0^{\pi} \frac{1}{2}\frac{k\eta I L \sin\theta}{2\pi^2 r}\frac{k I L \sin\theta}{2\pi^2 r} r^2 \sin\theta \, d\theta \, d\phi \\
&= 2\pi \frac{\eta k^2 I^2 L^2}{8\pi^4} \int_0^{\pi} \sin^3\theta \, d\theta \\
&= \frac{\eta k^2 I^2 L^2}{4\pi^3} \underbrace{\int_0^{\pi} \sin^3\theta \, d\theta}_{\frac{4}{3}} \\
&= \frac{\eta k^2 I^2 L^2}{3\pi^3}
\end{aligned}
$$

Since $P_T = \frac{1}{2} I^2 R_a$, then radiation resistance is solved as

$$R_a = \frac{2\eta k^2 L^2}{3\pi^3}$$

Interestingly, this is slightly higher than the electrically short monopole. And with no reactive impedance component, this should be easier to match than the short, straight dipole.

4. **Aircraft Communications:**

(a) EIRP = P_T + G_T (log scale) = 11 dBW

(b) From logarithmic link budget:

$$P_R = \mathrm{EIRP} + G_R - 20\log_{10}\left(\frac{4\pi}{\lambda}\right) - 20\log_{10} r$$

where $\lambda = 0.43$ m at 700 MHz, r is TR separation distance, $G_R = 6$ dBi, and P_R=114 dBW. Solving for r gives a range of 158 kilometers.

(c) There is a mismatch factor of 0.64 on the link (1.9 dB). All else being equal, a received power of -86 dBm now corresponds to a link distance of 120 kilometers, nearly a 20% decrease.