## Electromagnetics



## Polarization:

Why do we care??

- Antenna applications -
- Antenna can only TX or RX a polarization it is designed to support. Straight wires, square waveguides, and similar rectangular systems support linear waves (polarize
Remote Sensing and Radar Applications -
- Many targets will reflect or absorb EM waves differently for different polarizations. Using multiple polarizations can give different information and improve results.
- Absorption applications -
- Human body, for instance, will absorb waves with $E$ oriented from head to toe better than side-to-side, esp. in grounded cases. Also, the frequency a which maximum absorption occurs is different for these two polarizations. This has ramifications in safety guidelines and studies.


## Polarization

- In general, plane wave has 2 components; in $\boldsymbol{x} \& \boldsymbol{y}$

$$
E(z)=\hat{x} E_{x}+\hat{y} E_{y}
$$

- And $y$-component might be out of phase wrt to $x$-component, $\delta$ is the phase difference between $x$ and $y$.

$$
\begin{aligned}
& E_{x}=E_{o} e^{-j \beta z} \\
& E_{y}=E_{o} e^{-j \beta z+\delta}
\end{aligned}
$$



## Several Cases

- Linear polarization: $\delta=\delta_{\mathrm{y}}-\delta_{\mathrm{x}}=0^{\circ}$ or $\pm 180^{\circ} \mathrm{n}$
- Circular polarization: $\delta_{\mathrm{y}}-\delta_{\mathrm{x}}= \pm 90^{\circ} \& E_{o x}=E_{\text {oy }}$
- Elliptical polarization: $\delta_{y}-\delta_{x}= \pm 90^{\circ} \& E_{o x} \neq E_{o y}$ or $\delta=\neq 0^{\circ}$ or $\neq 180^{\circ} \mathrm{n}$ even if $E_{o x}=E_{\text {oy }}$
- Unpolarized- natural radiation


## Linear polarization

- $\delta=0$

$$
\begin{aligned}
& E_{x}=E_{o} e^{-j \beta z} \\
& E_{y}=E_{o} e^{-j \beta z}
\end{aligned}
$$

- @z=0 in time domain
$E_{x}=E_{x o} \cos (\omega \mathrm{t})$



## Circular polarization

- Both components have same amplitude $E_{o x}=E_{\text {oy }}$
- $\delta=\delta_{\mathrm{y}}-\delta_{\mathrm{x}}=-90^{\circ}=$ Right circular polarized (RCP)
- $\delta=+90^{\circ}=\mathrm{LCP}$



## Elliptical polarization



- $X$ and $Y$ components have different amplitudes $E_{o x} \neq E_{\text {oy }}$ and $\delta= \pm 90^{\circ}$
- $\operatorname{Or} \delta \neq \pm 90^{\circ}$ and $E_{o x}=E_{o y}$

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$\quad$ Parámetros de la elipse
$A R=$ axial ratio $=o a / o b$
$t \tan 2 \tau=\tan 2 \gamma \cos \delta$
$\sin 2 \varepsilon=\sin 2 \gamma \sin \delta$
$\cot |\varepsilon|=A R$
$\gamma=\tan ^{-1}\left(\frac{E_{y o}}{E_{x o}}\right)$

## Polarization Loss Factor PLF

$$
\begin{aligned}
& \hat{\rho}=\frac{\vec{E}}{|E|} \\
& P L F=\left|\hat{\rho}_{i} \bullet \rho_{a}^{*}\right|^{2}
\end{aligned} \quad P L F=\left|\hat{\rho}_{t} \bullet \hat{\rho}_{r}^{*}\right|^{2}
$$

## Poincaré Sphere

- Plots any possible state of polarization


