ECE 3317
Applied Electromagnetic Waves

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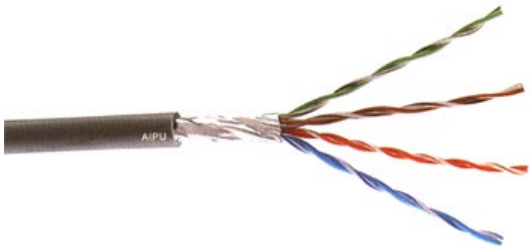
Fall 2023

Notes 14
Transmission Lines
(Discontinuity Effects)



Discontinuity Effects

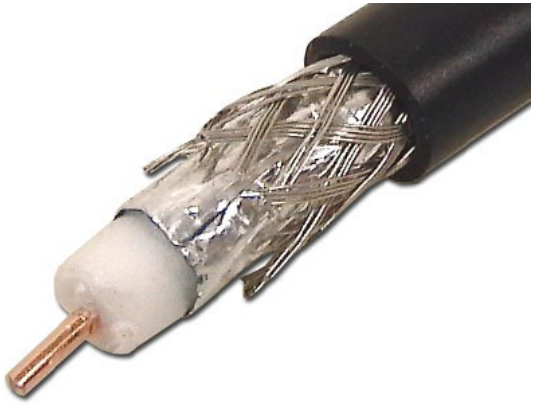
Two effects not predicted by transmission line theory:

- Reflections from discontinuities
- Radiation from discontinuities

Any practical system will have discontinuities.

Discontinuity Effects (cont.)

The discussion here will mainly focus on two common types of transmission lines, coaxial cable and twin lead, but the discussion is general and applies to other similar types of lines.

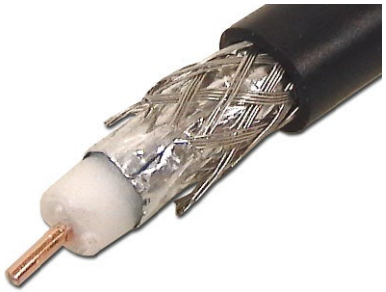


Coaxial cable

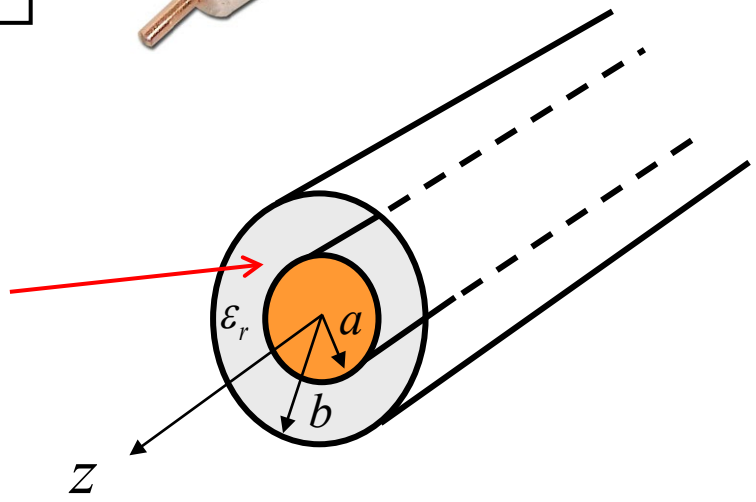
Twin lead

Coaxial Cable

The coaxial cable is a perfectly shielded system – there is never any radiation.



The fields are confined to the region between the two conductors.

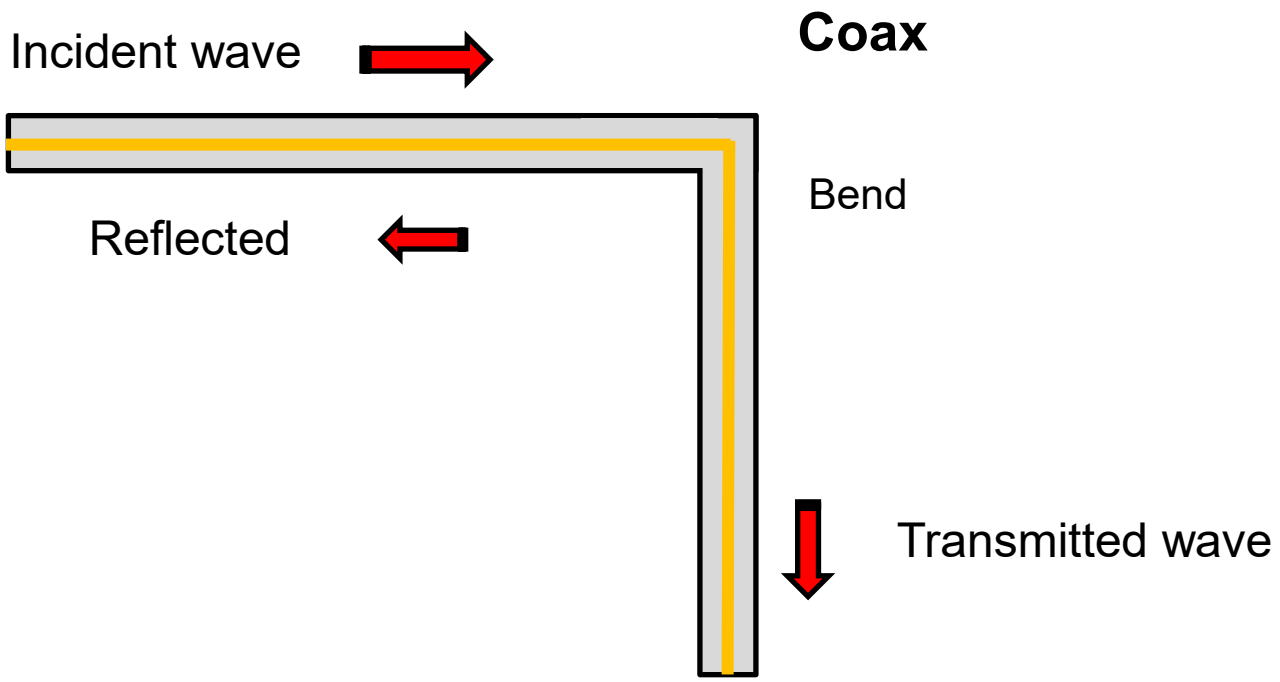


The coax does not interfere with anything, nor pick up interference from anything.

Assumption: The conductor thickness is large compared to a skin depth.

Coaxial Cable (cont.)

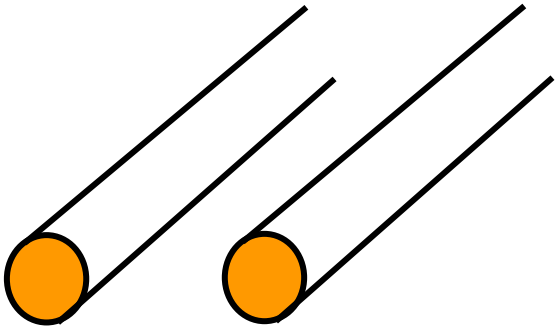
Reflections can still occur at bends.

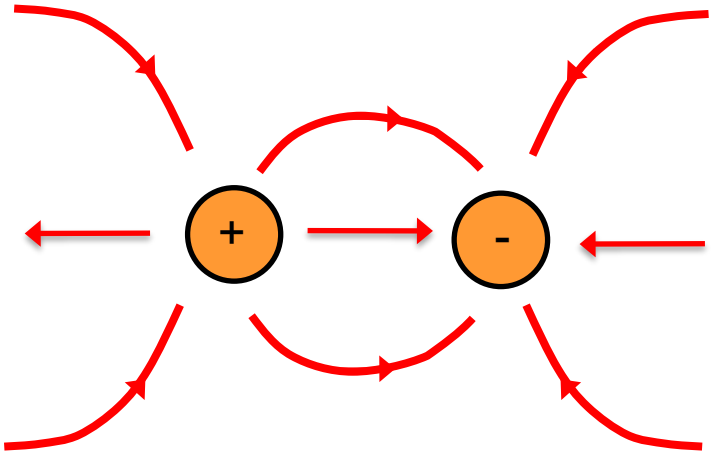


It is good to keep the radius of curvature of the bend large compared with the diameter of the coax.

Twin Lead

The twin lead is an open type of transmission line – the fields extend out to infinity.



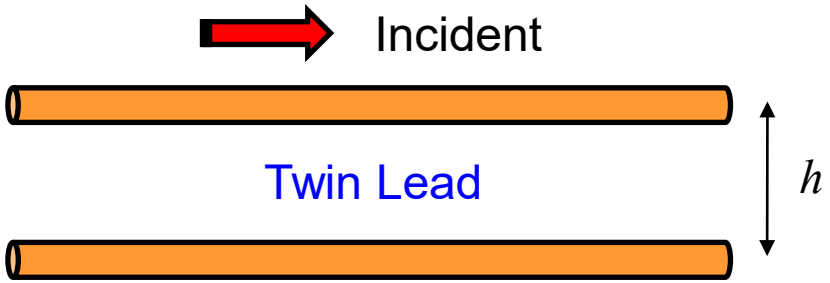


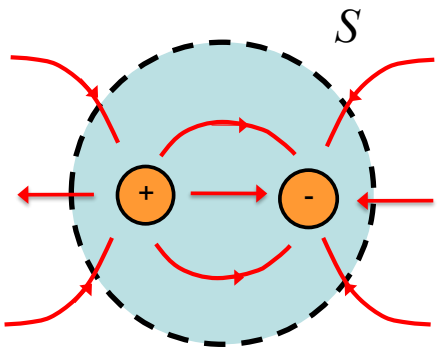
The fields may cause interference with nearby objects (or cause the twin lead to pick up interference).

Twin Lead (cont.)

An infinite straight twin lead transmission line will not radiate, even though the fields extend to infinity.

$$P_S = \int_S \mathrm{Re}\left(\frac{1}{2}\left(\underline{E}\times\underline{H}^*\right)\right)\cdot\hat{\underline{\rho}}\;\rho\,d\phi\,dz = 0$$





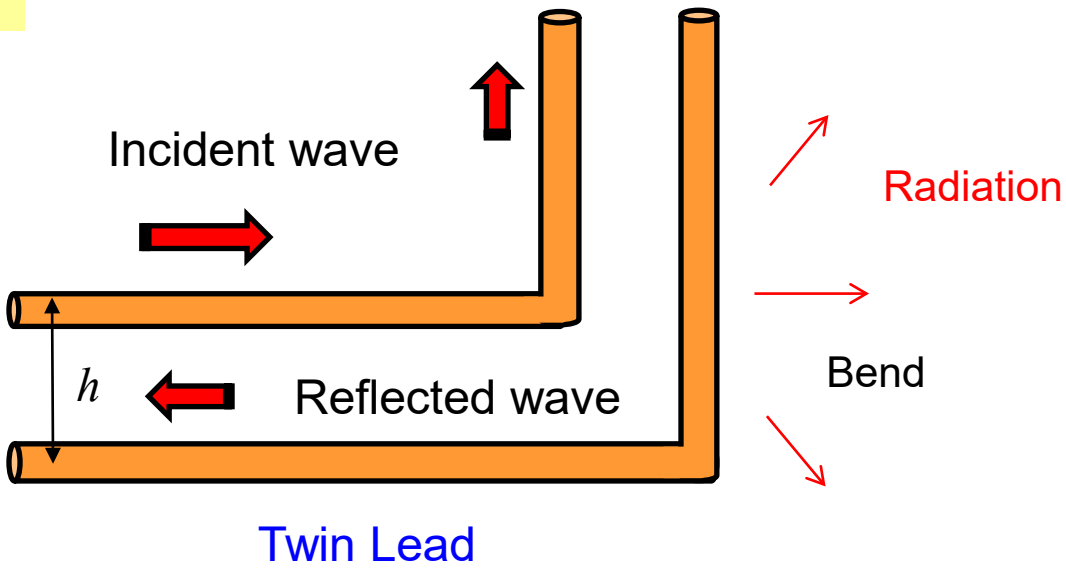
A transmission line wave represents an exact solution to Maxwell's equations on an *infinite straight line*.

(This wave has no attenuation on a lossless line, and hence no radiation.)

Twin Lead (cont.)

A discontinuity on the twin lead will cause radiation and reflections.

Example: Bend

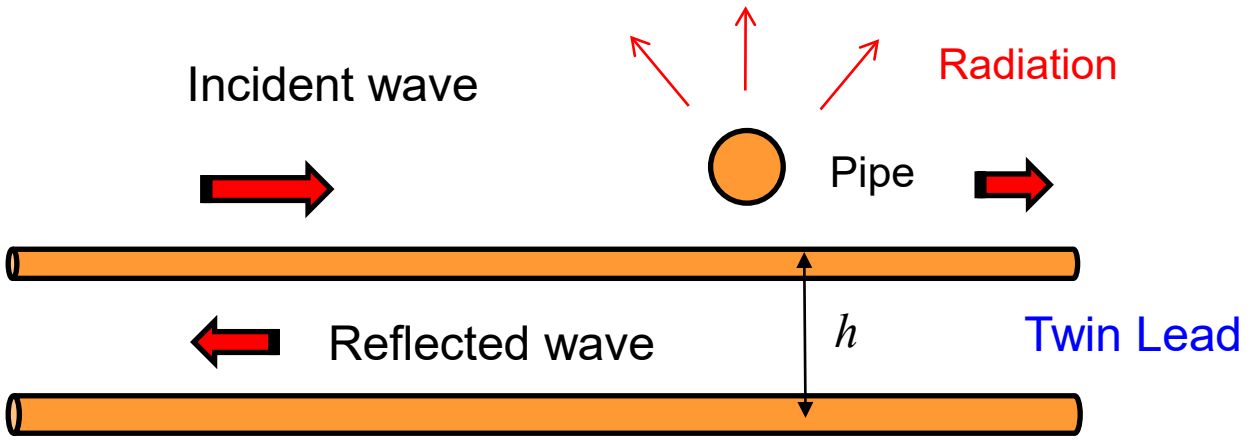


Note:
Radiation effects increase as the frequency increases.

Twin Lead (cont.)

A discontinuity on the twin lead will cause radiation and reflections.

Example: Obstacle (e.g., a pipe)

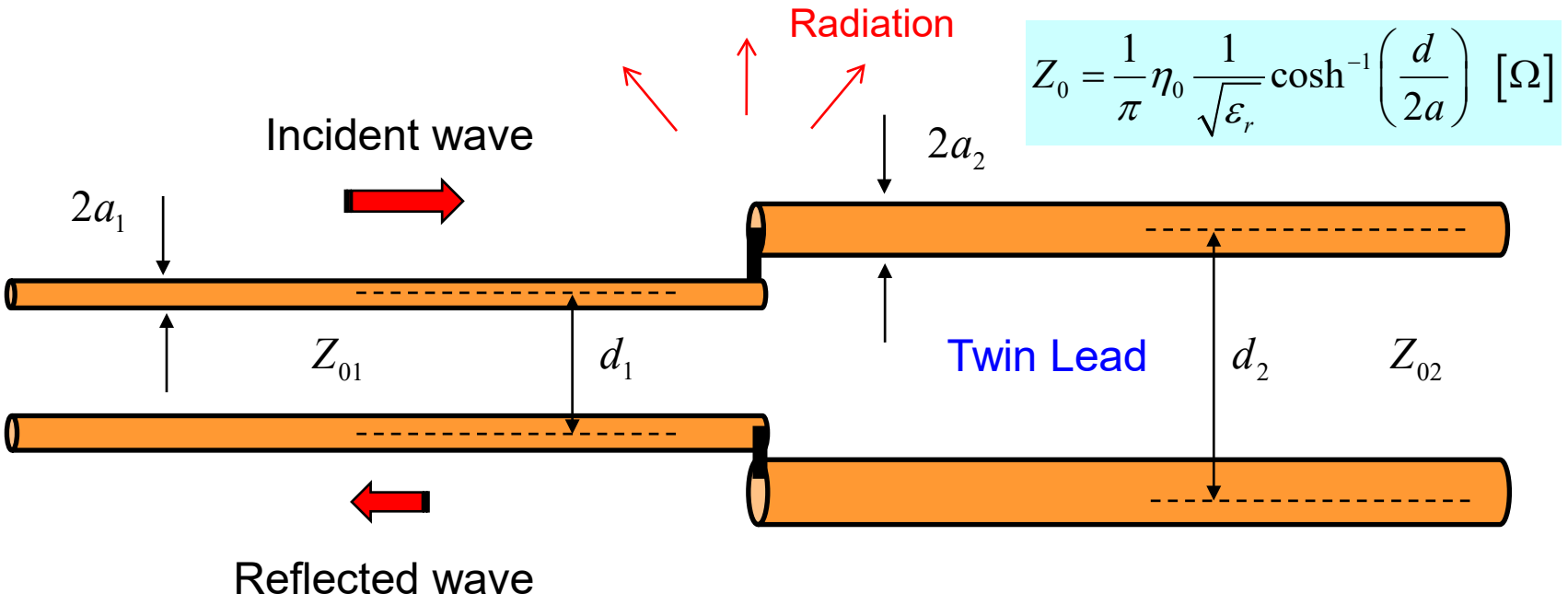


Note:
Radiation effects increase as the frequency increases.

Twin Lead (cont.)

A discontinuity on the twin lead will cause radiation and reflections.

Example: Change in dimensions



$$Z_0 = \frac{1}{\pi}\eta_0 \frac{1}{\sqrt{\varepsilon_r}} \cosh^{-1}\left(\frac{d}{2a}\right) \quad [\Omega]$$

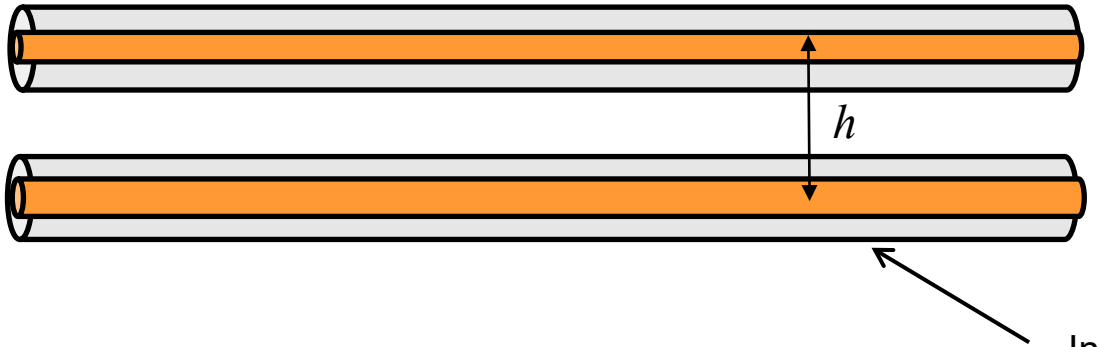
$$\frac{d_2}{a_2} = \frac{d_1}{a_1} \Rightarrow Z_{01} = Z_{02} = Z_0$$

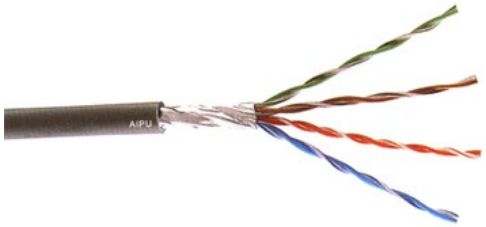
Transmission line theory predicts no reflections (same Z_0) – but there will be reflections at high frequency, along with radiation.

Twin Lead (cont.)

To reduce reflection and radiation effects at discontinuities:

1) Reduce the separation distance h (keep $h << \lambda$).
2) Twist the lines (twisted pair).





CAT 5 cable
(twisted pair)

Microstrip

At discontinuities, the following effects occur at high frequency:

1) Reflections
2) Radiation
3) Excitation of a surface wave

None of these effects are predicted by transmission-line theory.