3 Microwave Components

Let's carefully examine each of the **microwave devices** that are useful for radio design:

A. Transmission Lines
B. Amplifiers
C. Mixers
D. Oscillators
E. Isolators/Circulators
F. Switches and Attenuators
G. Power Dividers/Couplers
H. Filters

A. Transmission Lines

Perhaps the most **common** transmission line structure is **coaxial** transmission line.

HO:Coaxial Transmission Lines

Coaxial transmission lines are used with **connectorized** devices.

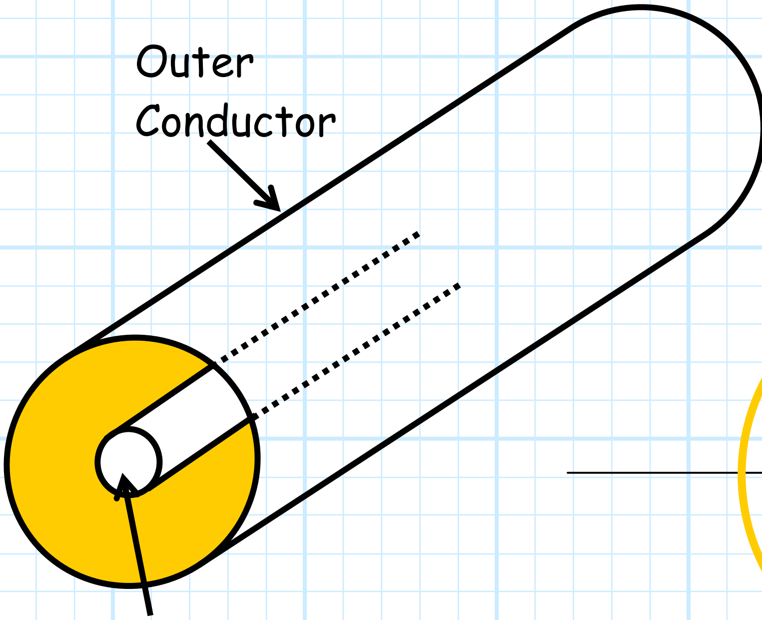
HO: Coax Connectors

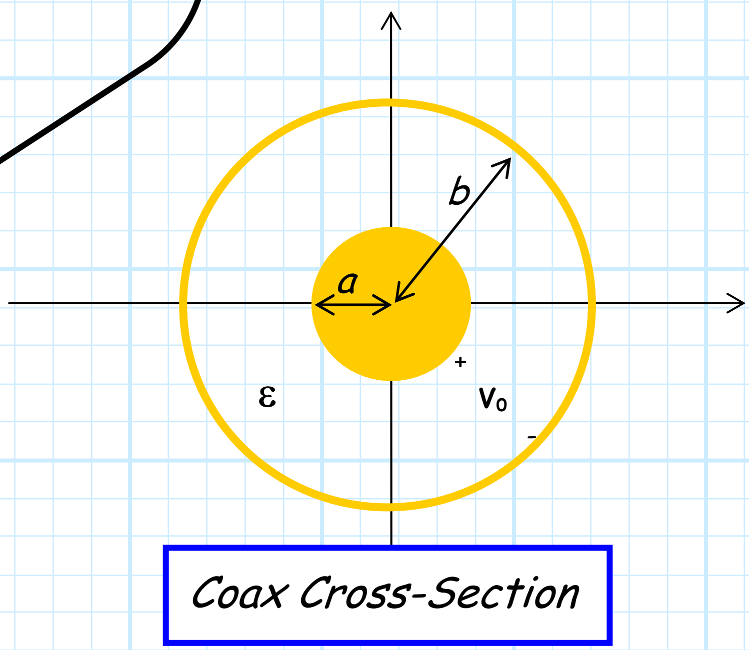
We can also construct transmission lines on printed **circuit boards**.

HO: Printed Circuit Board Transmission Lines

Coaxial Transmission Lines

The most **common** type of transmission line!

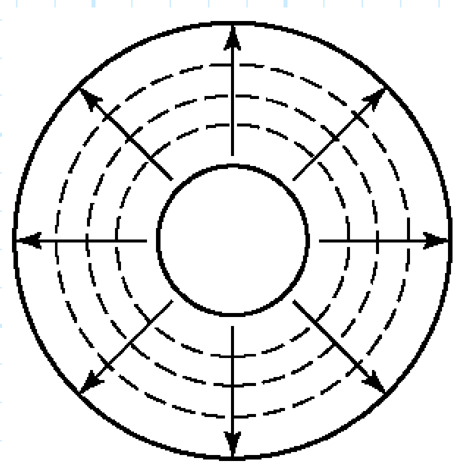




The **electric** field (⟶)points in the direction $\hat{a}_\rho$.

The **magnetic** field (- - - -)points in the direction $\hat{a}_\phi$.

E. M. Power flows in the direction $\hat{a}_z$.



➡ A TEM wave!

Recall from EECS 220 that the **capacitance** per/unit length of a coaxial transmission line is:

$$C = \frac{2\pi\varepsilon}{\ln[b/a]} \qquad \left[\frac{\text{farads}}{\text{meter}}\right]$$

And that the **inductance** per unit length is :

$$L = \frac{\mu_0}{2\pi}\ln\left[\frac{b}{a}\right] \qquad \left[\frac{\text{Henries}}{\text{m}}\right]$$

Where of course the **characteristic impedance** is:

$$\begin{aligned} Z_o &= \sqrt{\frac{L}{C}} \\ &= \frac{1}{2\pi}\sqrt{\frac{\mu_0}{\varepsilon}}\ln\left[\frac{b}{a}\right] \end{aligned}$$

and:

$$\beta = \omega\sqrt{LC} = \omega\sqrt{\mu_0\,\varepsilon}$$

Therefore the **propagation velocity** of each TEM wave within a coaxial transmission line is:

$$v_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{\mu_0\,\varepsilon}} = \frac{1}{\sqrt{\mu_0\,\varepsilon_0}}\frac{1}{\sqrt{\varepsilon_r}} = c\frac{1}{\sqrt{\varepsilon_r}}$$

where $\varepsilon_r = \varepsilon/\varepsilon_0$ is the relative dielectric constant, and c is the "speed of light" ($c = 3\times10^8\ m/s$).

Note then that we can likewise express β in terms ε_r:

$$\beta = \omega\sqrt{\mu_0\, \varepsilon} = \omega\sqrt{\mu_0\, \varepsilon_0}\sqrt{\varepsilon_r} = \frac{\omega}{c}\sqrt{\varepsilon_r}$$

Now, the **size** of the coaxial line (*a* and *b*) determines **more** than simply Z_0 and β (*L* and *C*) of the transmission line. Additionally, the line radius determines the **weight** and bulk of the line, as well as its **power handling** capabilities.

Unfortunately, these two characteristics **conflict** with each other!

1. Obviously, to **minimize** the weight and bulk of a coaxial transmission line, we should make *a* and *b* as **small** as possible.

2. However, for a given line voltage, reducing *a* and *b* causes the **electric field** within the coaxial line to **increase** (recall the units of electric field are *V/m*).

A higher electric field causes **two** problems: first, it results in greater **line attenuation** (larger α); second, it can result in **dielectric breakdown**.

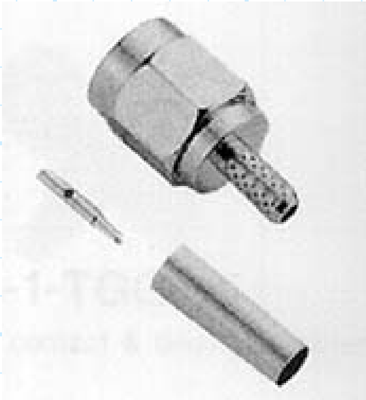
Dielectric breakdown results when the electric field within the transmission line becomes so large that the dielectric material is **ionized**. Suddenly, the dielectric becomes a **conductor**, and the value *G* gets **very** large!

This generally results in the **destruction** of the coax line, and thus must be **avoided**. Thus, **large** coaxial lines are required when extremely **low-loss** is required (i.e., line length ℓ is large), **or** the delivered **power** is large.

Otherwise, we try to keep our coax lines as **small** as possible!

Coaxial Connectors

There are many types of **connectors** that are used to connect coaxial lines to RF/microwave devices. They include:



SMA

The workhorse **microwave** connector. Small size, but works well to > 20 GHz. By microwave standards, moderately priced.

BNC

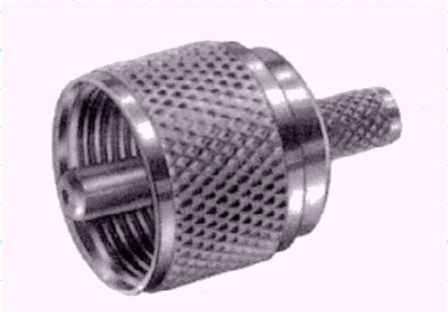
The workhorse **RF** connector. Relatively small and cheap, and easy to connect. Don't use this connector past 2 GHz!

F

A poorman's BNC. The RF connector used on most consumer products such as **TVs**. Cheap, but difficult to connect and not reliable.

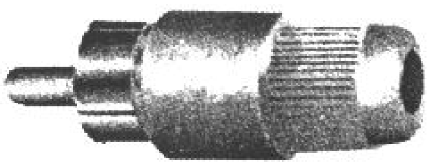
N

The **original** microwave connector. Good performance (up to 18GHz), and moderate cost, but large (about 2 cm in diameter) ! However, can handle greater **power** than SMA.



UHF

The poorman's **N.** About the same size, although **reduced** reliability and performance.



RCA

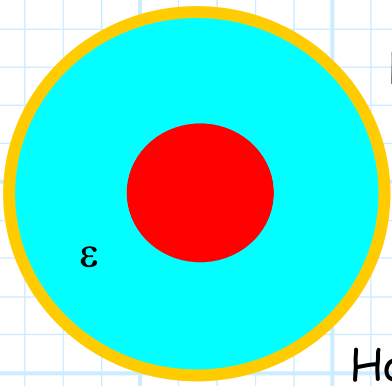
Not really an RF connector. Used primarily in consumer application for video and audio signals (i.e., <20 MHz). Cheap and easy to connect.

APC-7 and APC-3.5

The top of the line connector. Best performance, but cost **big $$$**. Used primarily in test equipment (e.g., network analyzers). 3.5 can work to nearly 40 GHz.

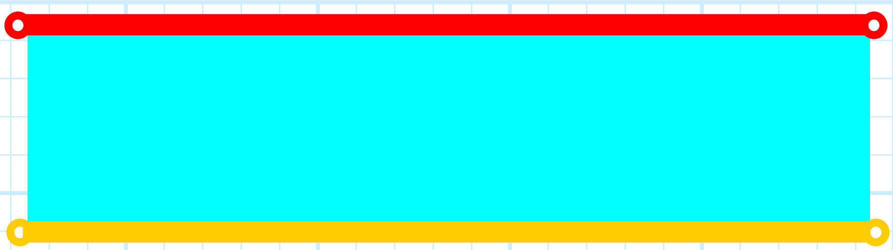
Printed Circuit Board Transmission Lines

Recall that a transmission line **must** consist of **two separate conductors**. Typically, the volume between these conductors is filled with a very low-loss **dielectric**.

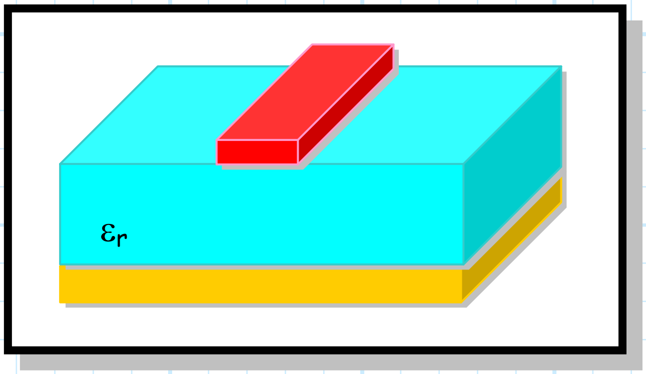


For example, a **coaxial** line has an inner conductor (conductor #1) and an outer conductor (conductor #2), with the cylindrical space between filled with dielectric.

However, we can likewise construct a transmission line using **printed circuit board** technology. The **substrate** of the circuit board is the dielectric that separates two conductors. The first conductor is typically a **narrow** etch that provides the **connection** between two components, while the second conductor is typically a **ground plane**.

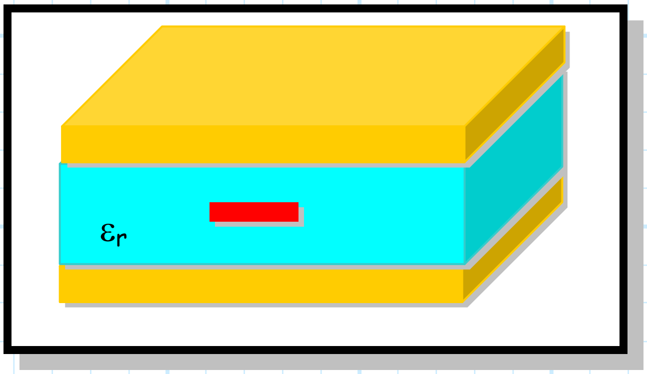


Below are some of the most popular types of printed circuit board transmission lines:



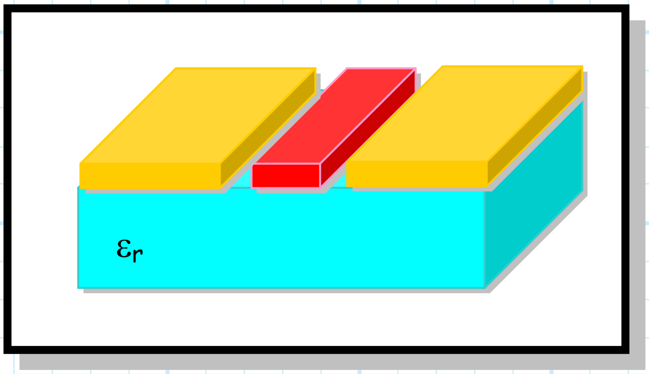
Microstrip

Probably most **popular** PCB transmission line. Easy fabrication and connection, yet is **slightly** dispersive, lossy, and difficult to analyze.



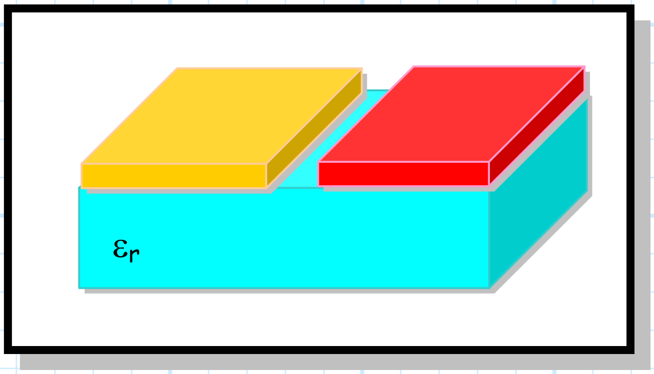
Stripline

Better than microstrip in that it is **not** dispersive, and is more easily analyzed. However, fabrication and connection is more difficult.



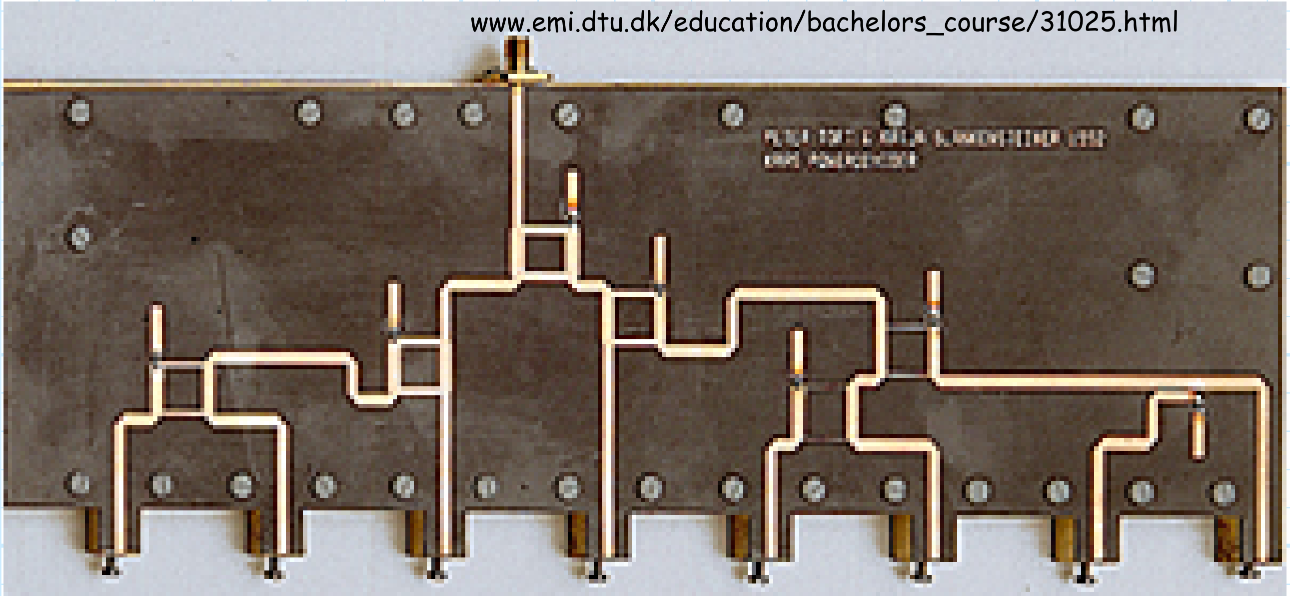
Coplanar Waveguide

The **newest** technology. Perhaps easiest to fabricate and connect components, as **both** ground and conductor are on one side of the board.

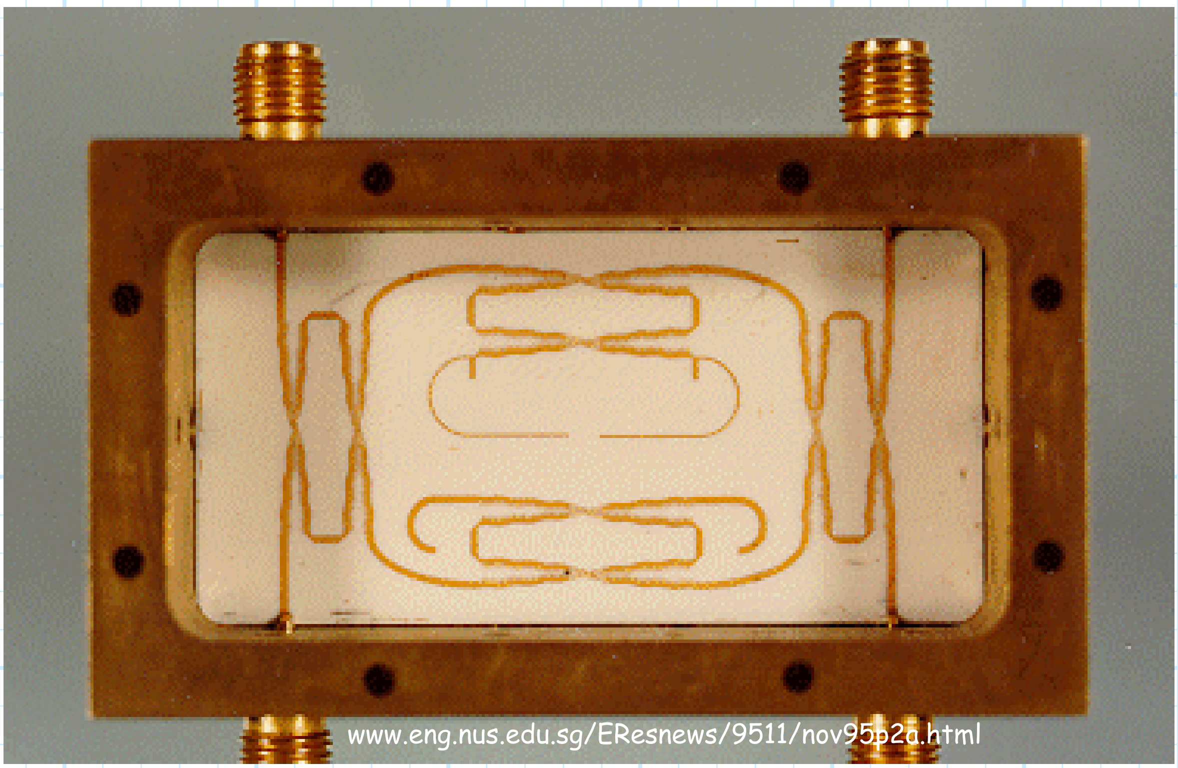


Slotline

Essentially, a dual wire tranmission line. Best for **"balanced"** applications. Not used much.



An antenna array feed, constructed using **microstrip** transmission lines and circuits.



A wideband **microstrip** coupler.