Project 2

Other planar transmission lines

This project is focused on the design of stripline and coplanar waveguides. It should give you a sense of which impedances are achievable and how to design lines of different sizes on a single material.

Task 1:
Using frequency $f = f_0$, make a design of transmission lines with characteristic impedances 25, 50, 75, 100 and 300 Ω of the following types:

- a stripline
- a coplanar waveguide without a ground plane (CPW)
- a coplanar waveguide with a ground plane (CPWG).

In cases where it is not possible to fabricate an impedance, determine the limiting impedance values.

Design considerations:

- suppose available etching technology with the achievable minimal width of a trace and the width of the gap as 0.1 mm
- use commercially available substrates (Rogers, Isola, Taconic, Crane, ...) with copper cladding with a thickness of 17 µm (0.5 oz. of Cu per area of square foot, 1 oz. ≈ 28.3 g)
- some examples of substrates from Rogers corp. with a wide variety of permittivity are:

Substrate name	Relative permittivity for design, ε_r (-)	Dissipation Factor, tanδ at 10 GHz (-)	Available thickness (mm)
RT/duroid 5880	2.2	0.0009	0.127, 0.254, 0.381, 0.508, 0.787, 1.575, 3.175
RO4350	3.66	0.0037	0.101, 0.168, 0.254, 0.338, 0.422, 0.508, 0.762, 1.524
TMM 6	6.3	0.0023	0.381, 0.508, 0.635, 0.762, 1.27, 1.524, 1.905, 2.54, 3.175, ...
TMM 10	9.2	0.0022	0.381, 0.508, 0.635, 0.762, 1.27, 1.524, 1.905, 2.54, 3.175, ...

- adjust the width of the strip and the gap of a 50 Ω grounded coplanar waveguide to be connected to SMA connectors 32K145-400L5 (pin diam. 0.92 mm, $w + 2g = 4.2$ mm), or 32K243-40ML5 (pin diam. 0.25 mm, $w + 2g = 2$ mm)
- ensure a single-mode propagation regime up to design frequency f_0 (CPW: $w + 2g < \lambda_g/2$, stripline: w, B < $\lambda_g/2$)

Task 2:
Design 50 Ω coplanar waveguides with a ground plane (CPWG) on a single substrate material with a single thickness suitable for a connection to:

- a wide band amplifier Qorvo CMD242K4 in a QFN package with pin width $w = 0.23$ mm and gap $g = 0.27$ mm, hence $w + 2g = 0.77$ mm
- fixed attenuator Mini-Circuits QAT-10+ in an MC3000 package with center pin width $w = 0.3$ mm and gap $g = 0.5$ mm, hence $w + 2g = 1.3$ mm
- an SMA connector Amphenol 132372 with center pin diameter $w = 0.8$ mm and gap width $g = 1.7$ mm, hence $w + 2g = 4.2$ mm

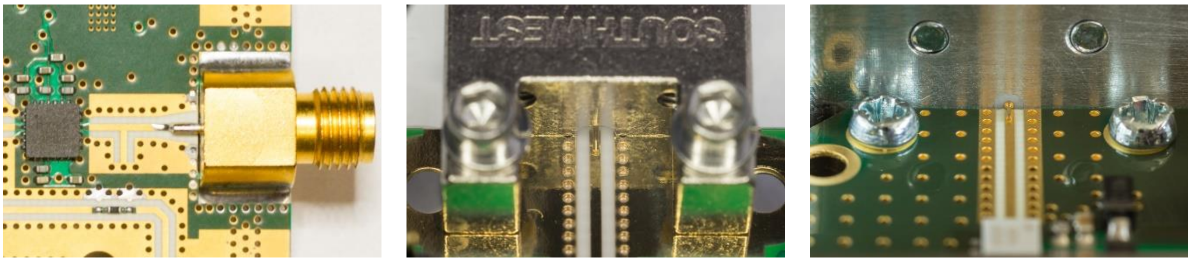
Analyze losses of these transmission lines in the frequency band 0.1 ÷ 20 GHz and present it on a single graph in dB/cm. Size $w + 2g$ should match the size of components with a tolerance up to ±50 µm.

Project solution procedure

Task 1:
This task can be completely solved utilizing the TXLine application. Select the proper tab, taking into consideration the transmission line parameters, and study which parameter of the substrate affects line's impedance and how. Always keep in mind that the characteristic impedance of the transmission line is (in simplified lossless case) $Z_0 = \sqrt{L/C}$, where *L* and *C* is series inductance and shunt capacitance per unit length, respectively. By changing either substrate permittivity or the height or width of the strip, capacitance *C* changes dominantly. Decreasing the height of the substrate increases the capacitance, hence decreasing impedance. Making the strip wider also increases the capacitance. Making a smaller gap in CPW(G) also increases the capacitance. Generally, for a low-impedance transmission line a thick substrate with low permittivity is needed and vice versa.

During stripline transmission line design keep in mind that the stripline is fabricated using two sheets of substrate, hence final thickness *B* is twice the utilized substrate thickness *H*.

When connecting the CPWG transmission line to a common end-launch connector, always try to minimize the size of a discontinuity. The CPWG is usually designed to match the distance between the inner edges of the grounds ($2g + w$) with the inner diameter of the outer coaxial line conductor. The situation is depicted in Fig. 1.



a) b) c)

Fig. 1 a) CPWG widening its gap towards the connector, b) end-launch connector from [Southwest Microwave] connected to the CPWG with a narrow center conductor, c) CPWG connected to the coaxial connector on the device's chassis.

The width of the strip usually fits the connector's center pin diameter well. In case of a significant size difference, a taper can be designed at the end of the strip, but this design is not the focus of the MIO subject. Line with the taper is shown in Fig. 2.

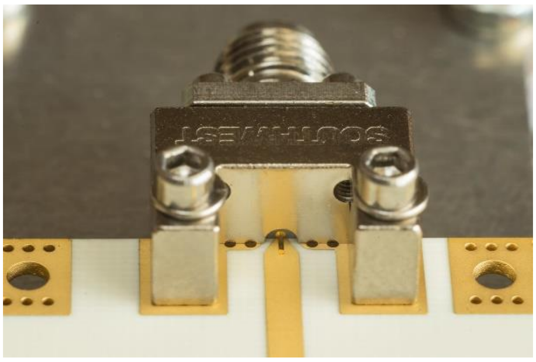
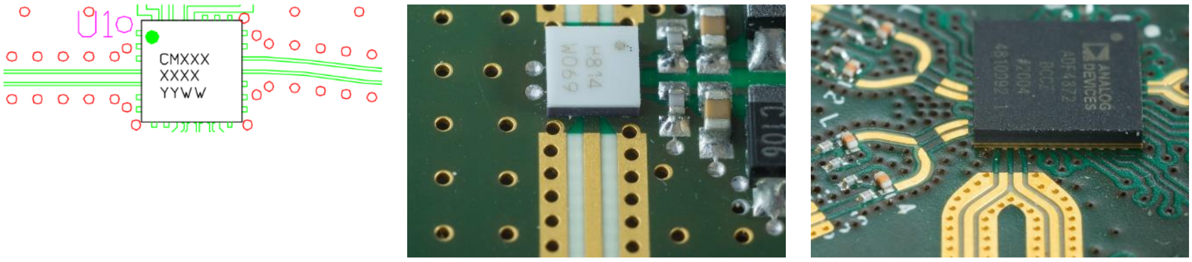


Fig. 2 Wide microstrip line with the taper connected to the end-launch connector.

Design all transmission lines without showing any errors or warnings in the TXLine application.

Task 2:

First, design the 50 Ω CPWG on the selected substrate at design frequency f_0 using TXLine to match the width of the overall CPWG ($2g + w$) with the size of the concerned chip or connector. Open the AWR, set the frequency band of simulation, create a schematic and introduce a proper substrate definition CPW_SUB for the coplanar components. Activate the bottom ground plane by setting Gnd=1. Add the CPW1LINE element into the schematic and set its designed parameters. The length of the line segment should be 1 cm in order to see the losses of the lines in dB/cm directly as its transmission coefficient. Connect 50 Ω ports to both ends of the lines and analyze the absolute value of its transmission coefficient in dB. If the transmission coefficient is wavy, the impedance is probably not 50 Ω exactly, and the width of the strip or gap should be slightly tuned. An example of a CPWG transmission line connected to an SMD QFN package can be seen in Fig. 3.



a) b) c)

Fig. 3 a) drawing of an ideal connection, b) connection with the end of the CPWG adapted to the QFN's contacts spacing ([HMC814]), c) a balanced signal connected to the QFN package using 2 CPWG lines ([ADF4372]).