We3H-319-FO607

Hybrid implementation of a compact 2-way Wilkinson power divider/combiner for applications in the low RF band

J. M. Lopez-Villegas[#1] and N. Vidal[#2]

[#]Department of Electronic and Biomedical Engineering, University of Barcelona, Spain

[1]j.m.lopez_villegas@ub.edu, [2]nvidal@ub.edu

UNIVERSITAT DE BARCELONA

Outline

- Introduction
- Fundamentals of Helical-microstrip TLs
- Design and Optimization of the Hybrid 2-way Wilkinson device
- Experimental
  - Manufacturing
  - EM Characterization
- Conclusions

Introduction (I)

- TL segments are widely used in the design of microwave components and circuits, including Wilkinson power divider/combiner, among others.
- The key design parameters are the characteristic impedance, Z_o and the electrical length, l_e , of the segments.
- In the GHz frequency range, $l_e \approx$ few cm at most
- At lower frequencies, the design is impractical unless a compaction procedure is applied.

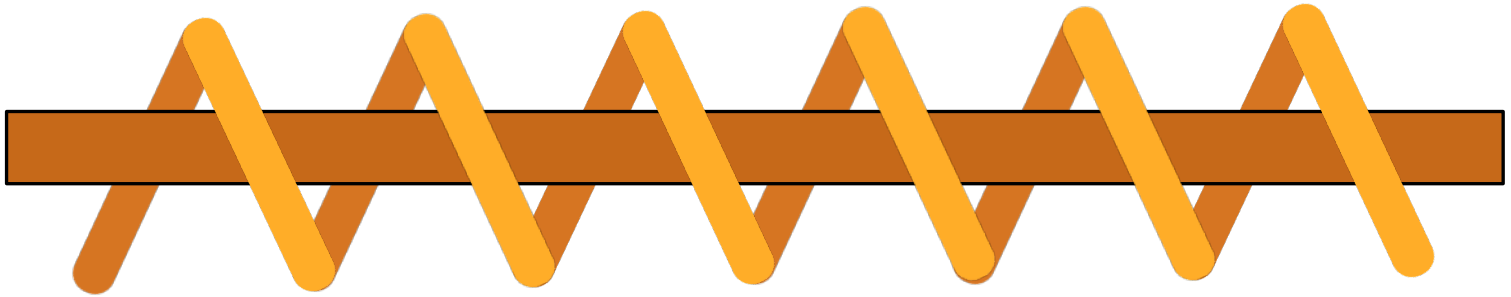
Introduction (II)

- Meandering is the usual compaction procedure used in planar technologies.

- However, each meander introduces a discontinuity in the signal path that must be accounted for.

Introduction (III)

- An alternative compaction procedure is to use helical TLs.
- The helical TL is a coaxial TL where one of the conductors is replaced by a helical spiral.



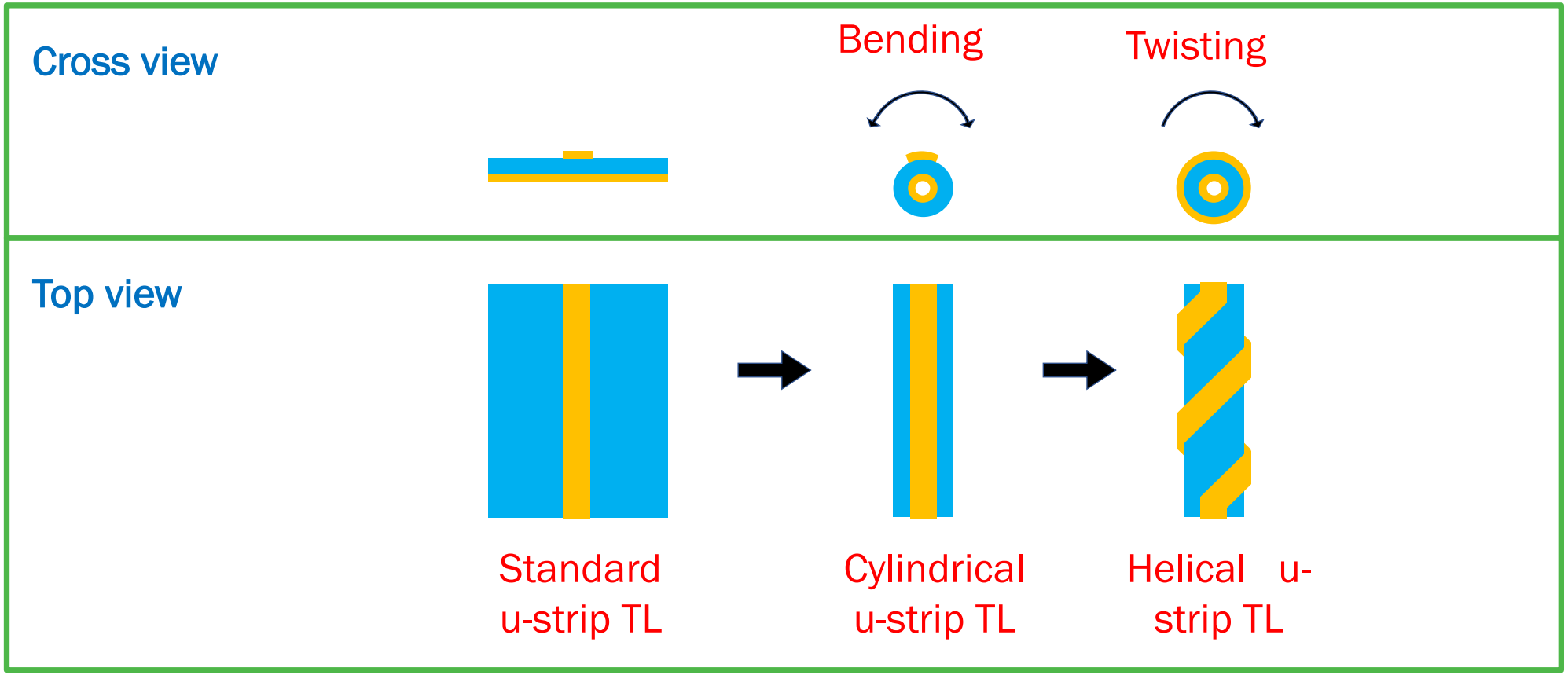
- If the helix cross section is a rectangle, we call it helical-microstrip TL.
- Due to the 3D nature of Helical TLs, there is no discontinuity in the signal path.

Introduction (IV)

- The main objectives of this work are:
  - The Design of a compact Wilkinson device using helical-microstrip TLs. Operating frequency in the low MHz RF band (250 MHz).
  - The integration of the device on a standard PCB to verify technological compatibility.
  - The evaluation of the compaction factor by comparing the proposed device with a standard planar implementation.
  - And the comparison of the proposed device with other compact implementations of Wilkinson devices in the literature.

Helical-microstrip TLs (I)

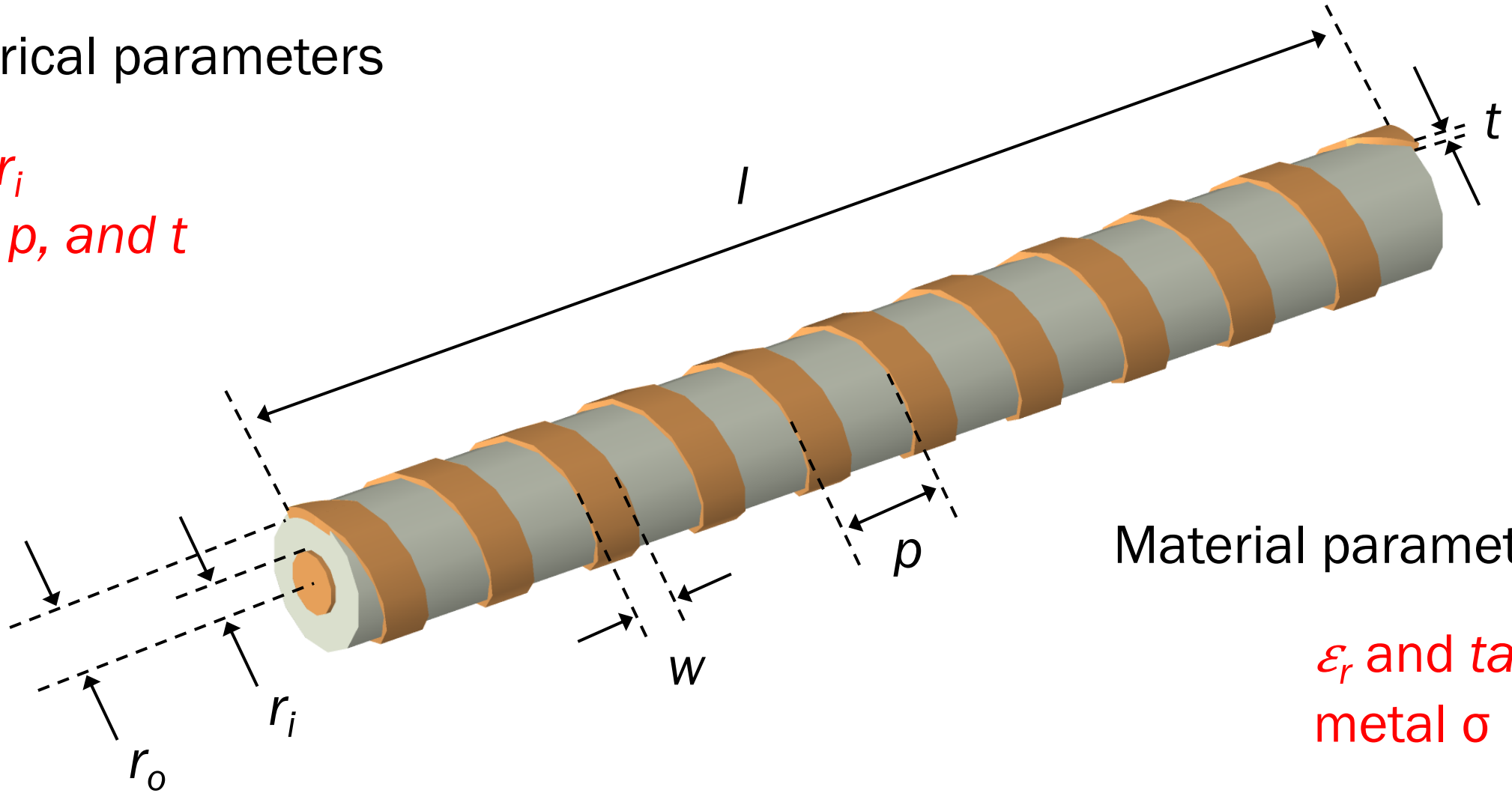
- From standard microstrip TL to Helical-microstrip TL



Helical-microstrip TLs (II)

Geometrical parameters

r_o and r_i
w, N, l, p, and t



Material parameters

ε_r and $tan(\delta)$
metal σ

Helical-microstrip TLs (III)

- Characteristic impedance, Z_o, and Electrical length, l_e, of the Helical-microstrip TL(1)

$$Z_o \approx \frac{120\pi}{\sqrt{\varepsilon_r}} \frac{h_{eff}}{w}$$

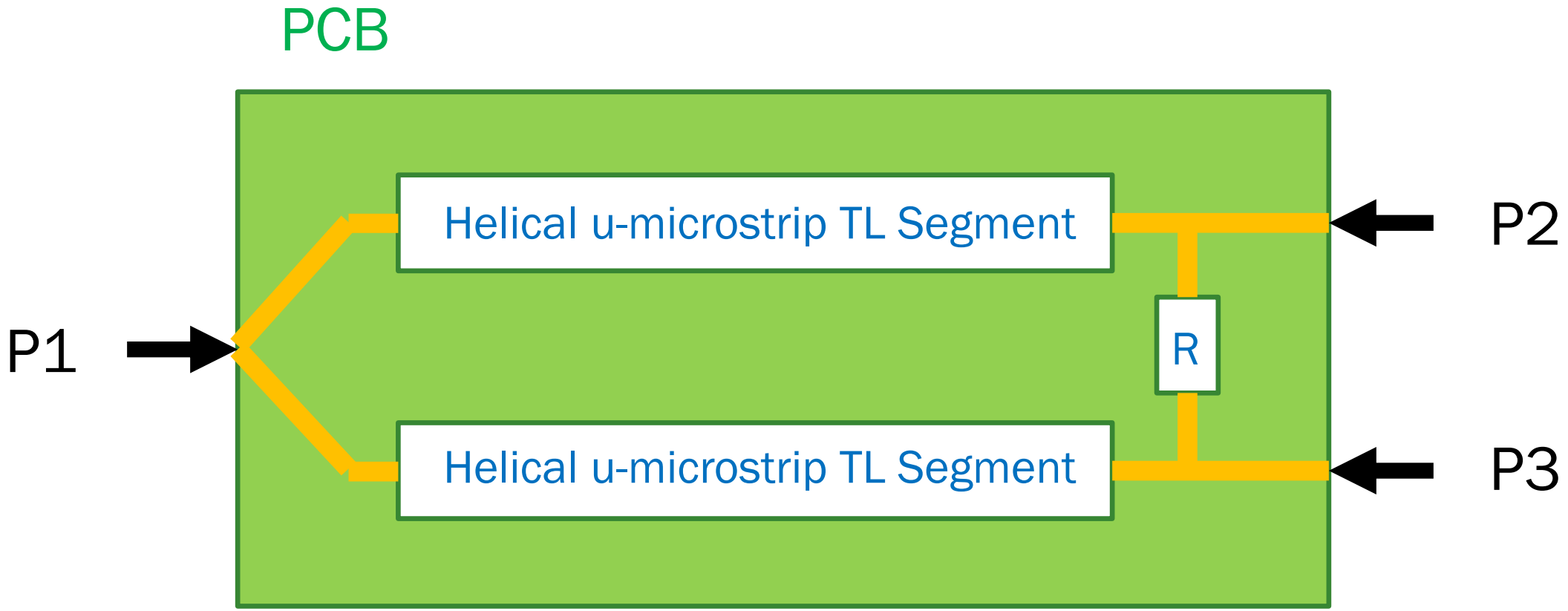
$$h_{eff} = r_o \ln\left(\frac{r_o}{r_i}\right)$$

$$l_e \approx \sqrt{\varepsilon_r}\, l'$$

$$l' = \sqrt{(2\pi r_o N)^2 + l^2}$$

(1) J. M. Lopez-Villegas, A. Salas and N. Vidal, "Modeling of 3-D-Printed Helical-Microstrip Transmission Lines for RF Applications," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 67, no. 12, pp. 4914-4921, Dec. 2019

Design of the Wilkinson device (I)



Schematic view of the proposed device

Design of the Wilkinson device (II)

- Target values of Z_o and l_e

$$Z_o = 50\sqrt{2}\ \Omega = 70.71\ \Omega$$

$$l_e = \left(\lambda/_4\right)@250\ MHz \approx 0.3\ m$$ Including the length of PCB traces

- Design constrains for mechanical stability

$$r_o - r_i = 1.57\ mm$$ to match the thickness of a FR4 PCB

$$r_i = 1.5\ mm$$ to use a standard 3 mm diameter copper, bar as the inner ground conductor

Design of the Wilkinson device (III)

- Variable design parameters

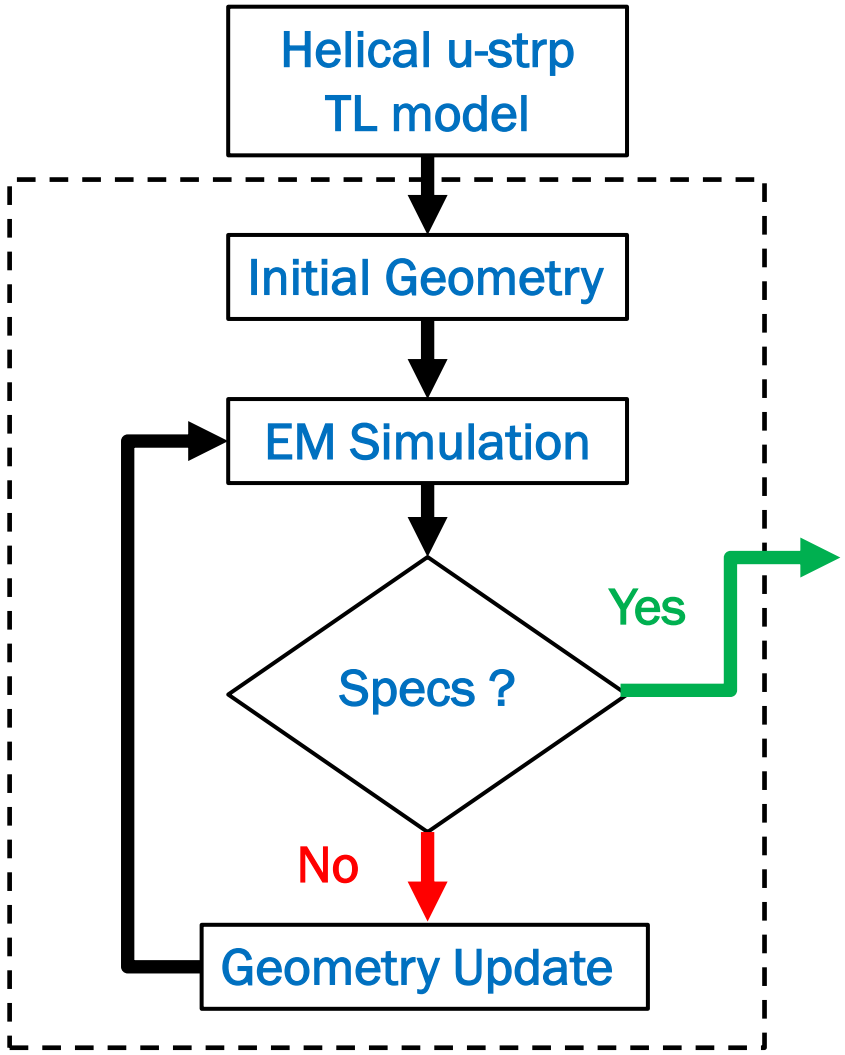
  w to adjust "Z_o"

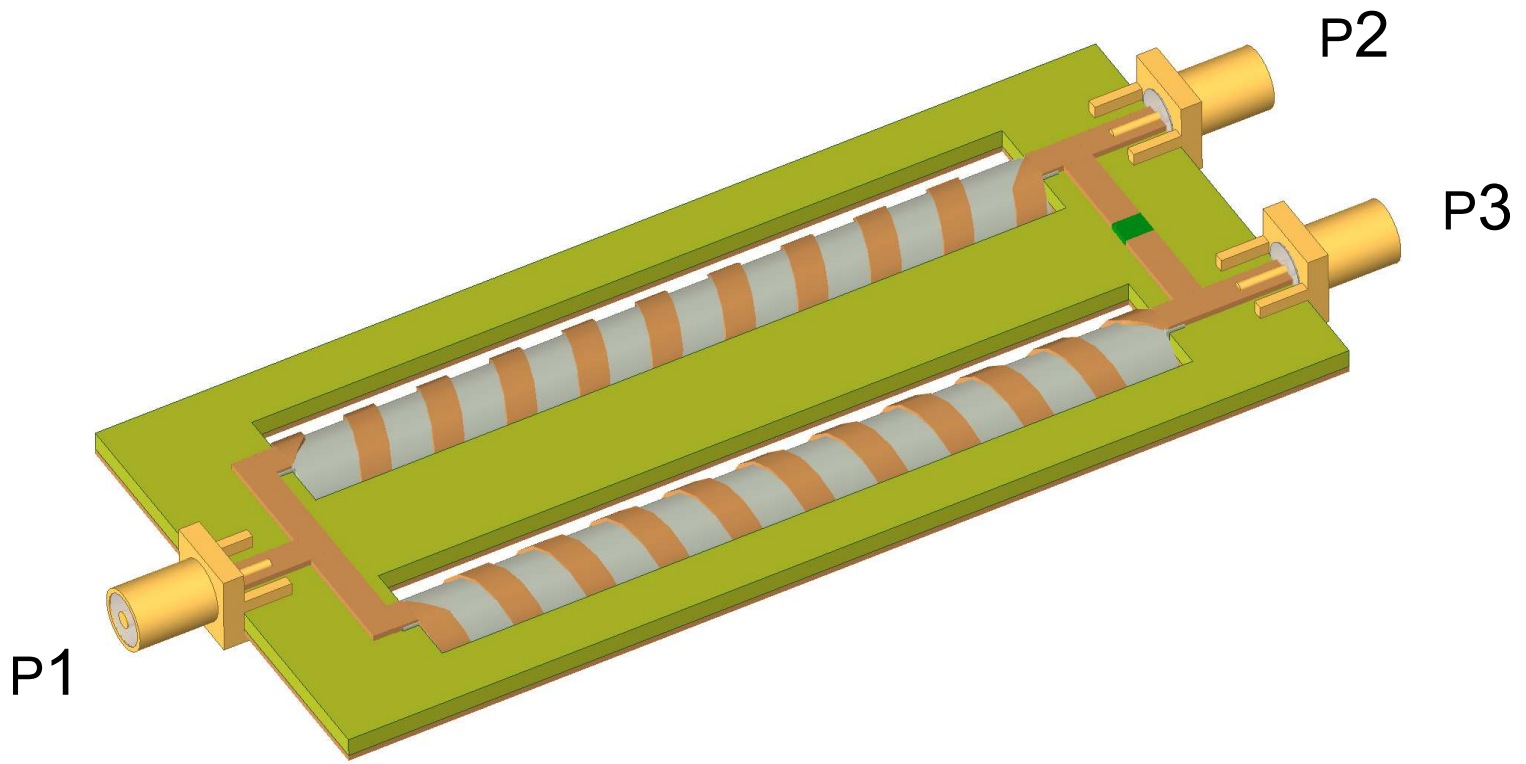
  l and N to adjust "l_e" and reduce as much as possible the length of PCB traces.

- Additional design consideration

  - Include SMA connectors.

Design of the Wilkinson device (IV)





EM model of the proposed Wilkinson device

Design of the Wilkinson device (V)

Final geometry

r_i = 1.5 mm

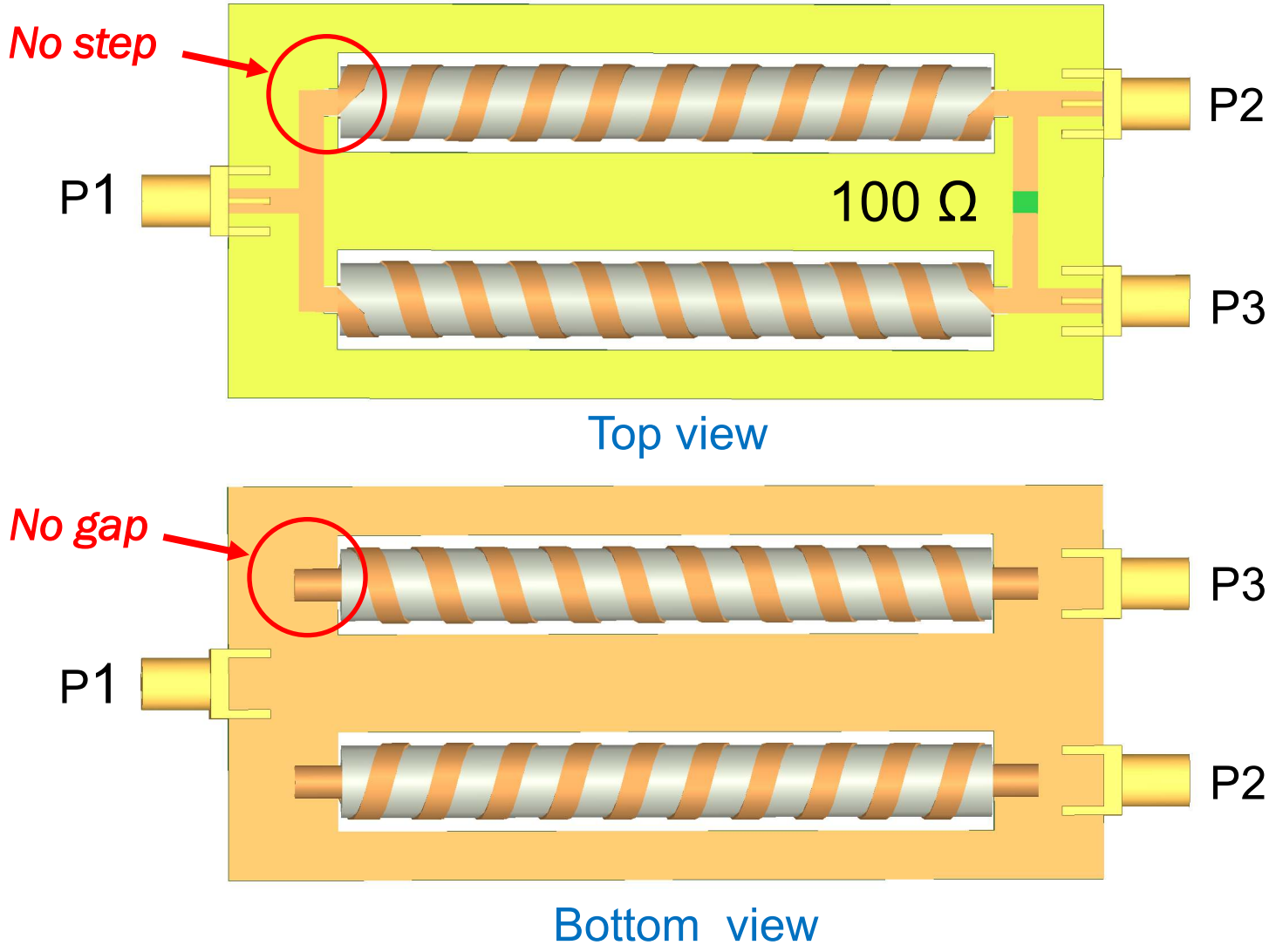
r_o = 3.07 mm

w = 2.3 mm

l = 60 mm

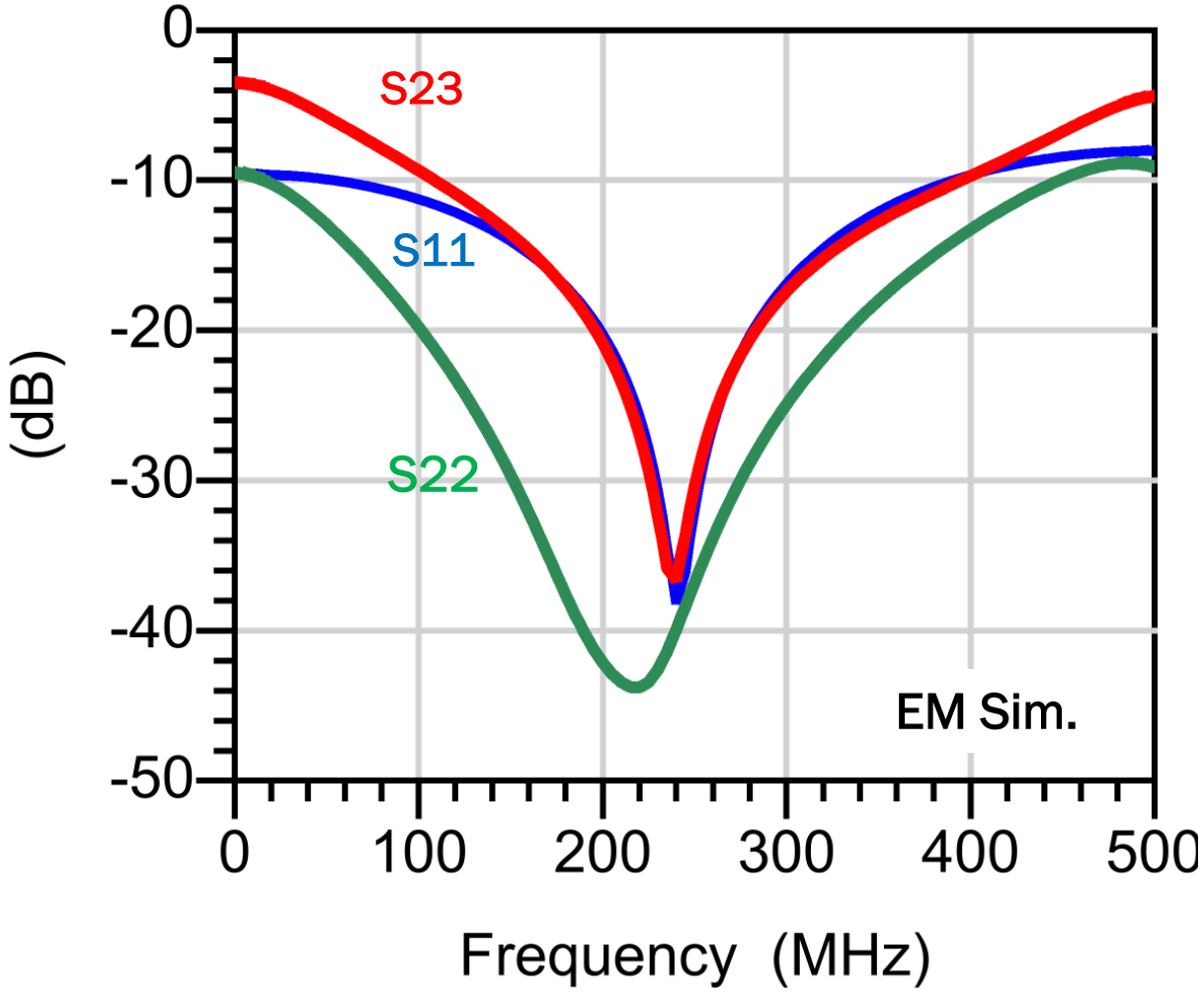
N = 10

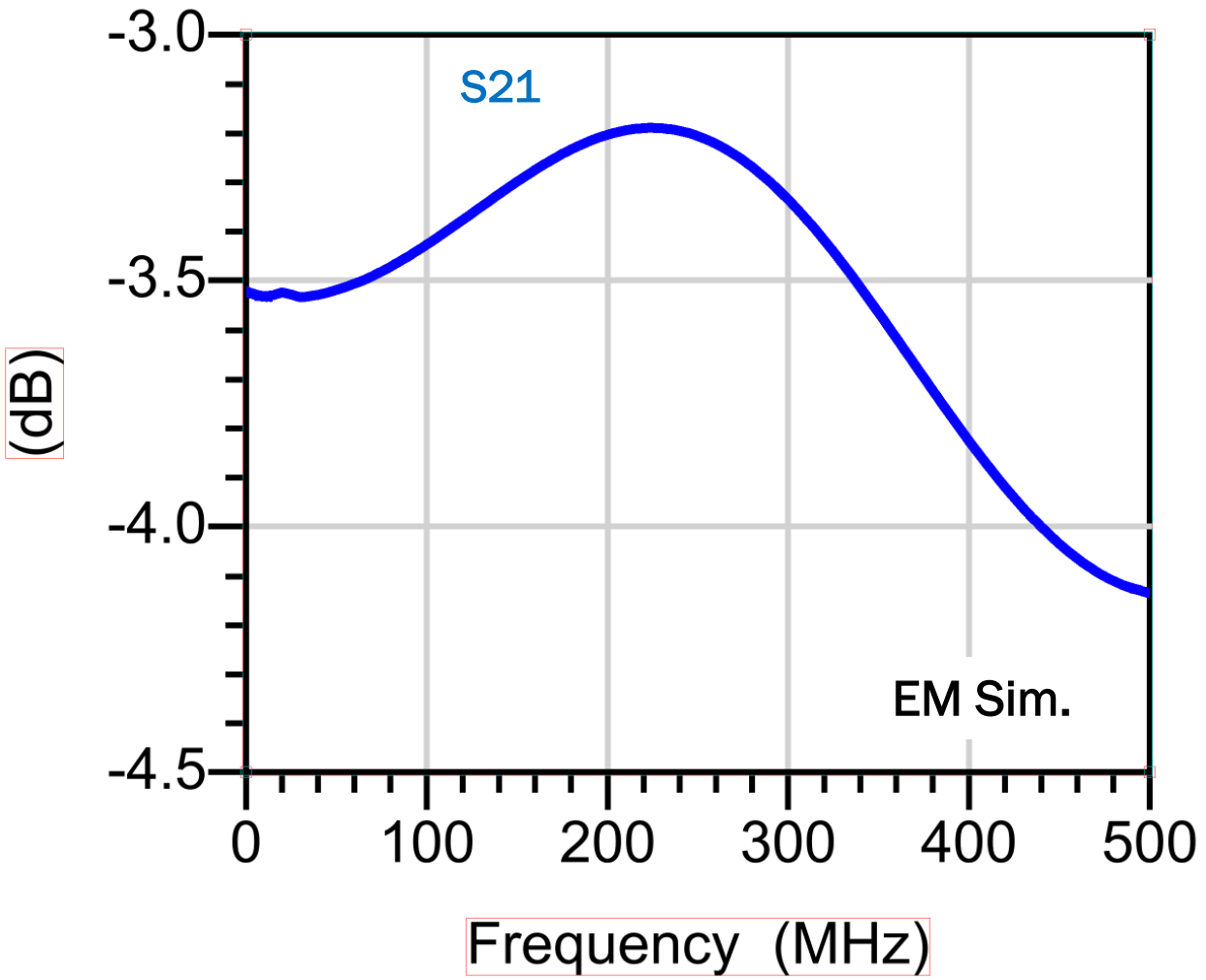
A = 98.5 mm x 30 mm *



* *Including SMA connectors*

Design of the Wilkinson device (VI)



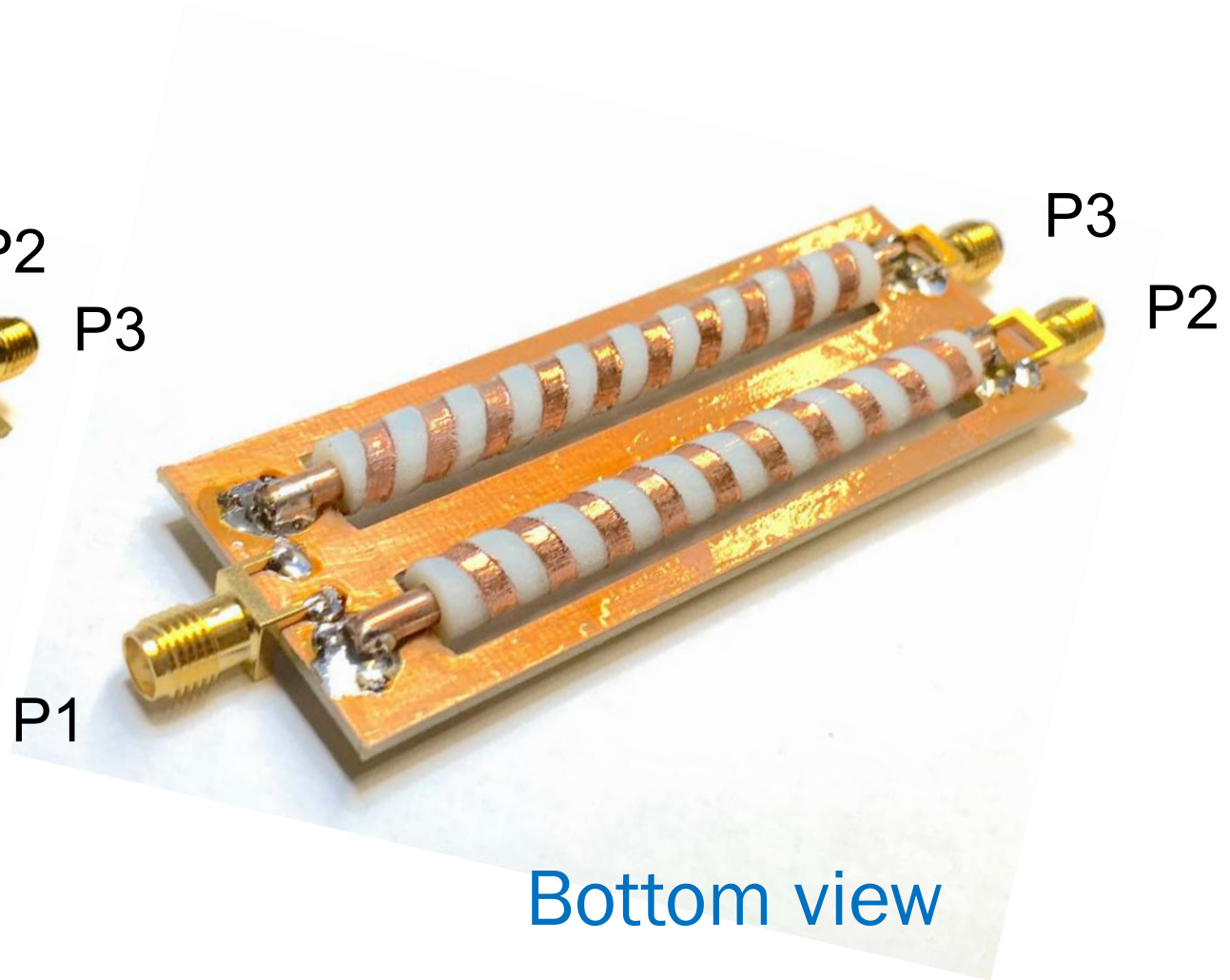


Experimental (I)

- Manufacturing
  - 1st "3D printing" dielectric base of the Helical-microstrip TL segments
  - 2nd "Copper Electroplating" metallization of the helical spiral
  - 3rd "Standard PCB process" board with traces, ground plane and openings
  - 4th "Assembling":
    - embedding of the helical microstrip TL segments
    - placement of the copper bar, the resistor and the SMA connectors
    - Welding

Experimental (II)

Top view



Bottom view

Experimental (III)

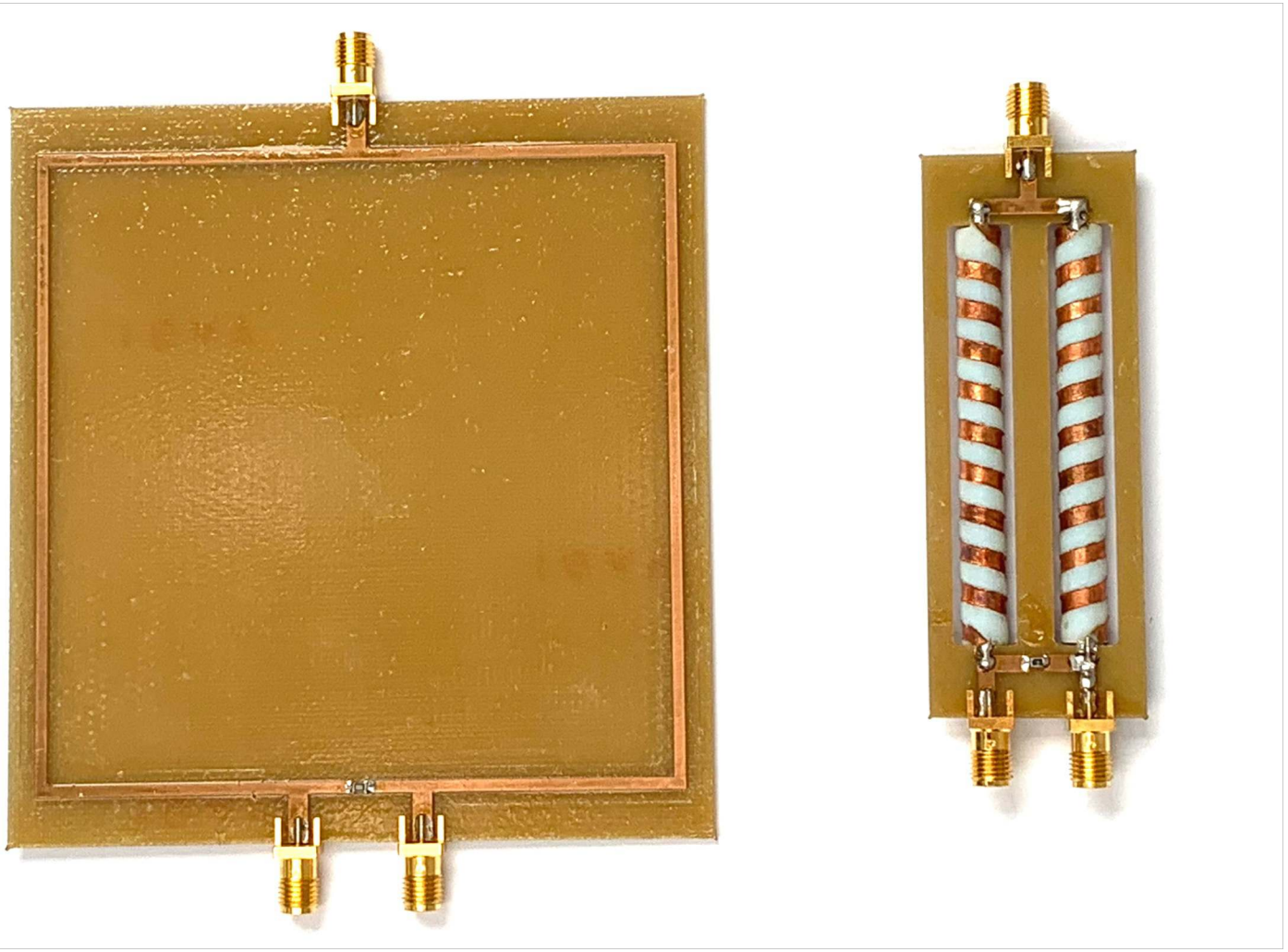
PCB vs Hybrid

f_c = 250 MHz

A_{PCB} = 112.5 mm x 100 mm

A_{hybrid} = 98.5 mm x 30 mm

75% reduction in area

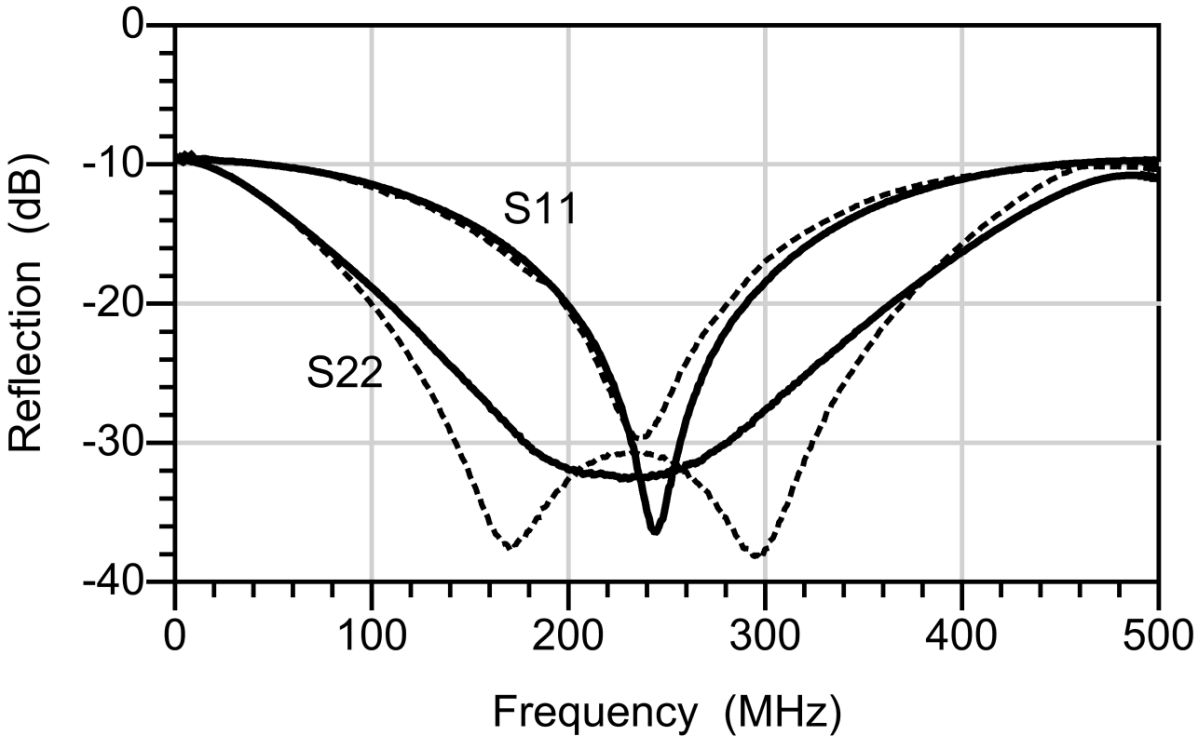


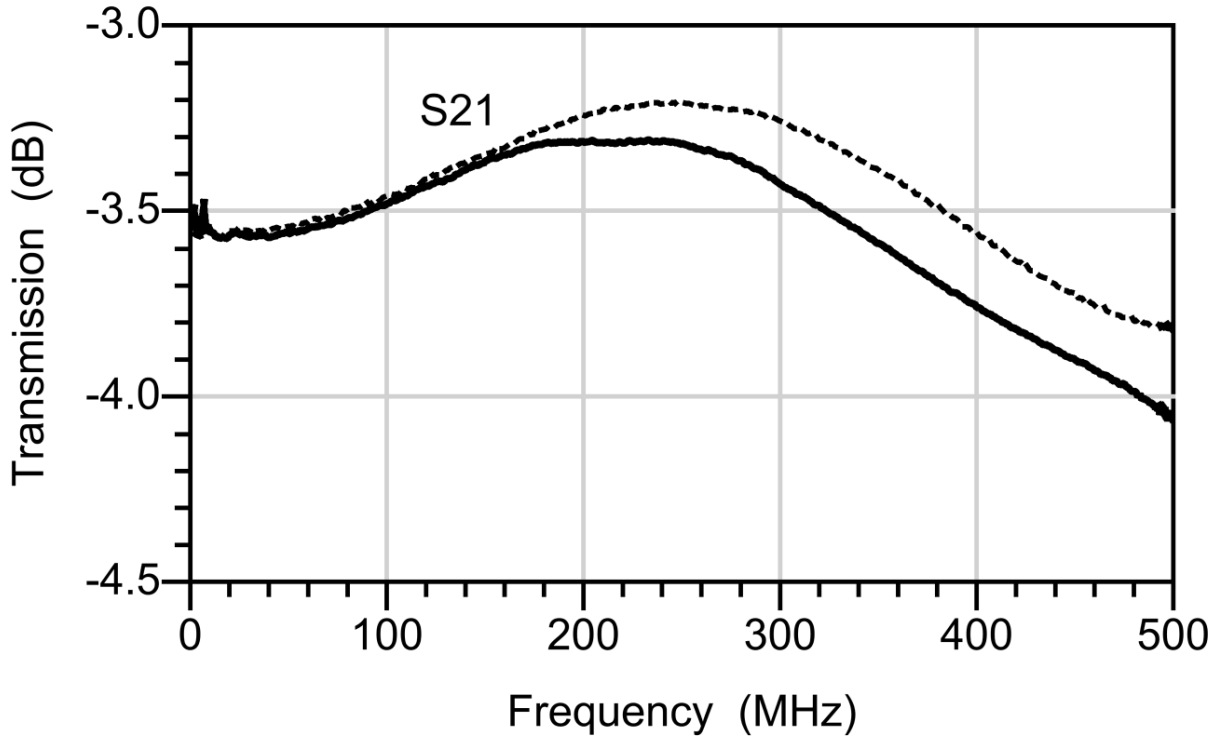
PCB device

Hybrid device

Experimental (IV)

- EM Characterization.

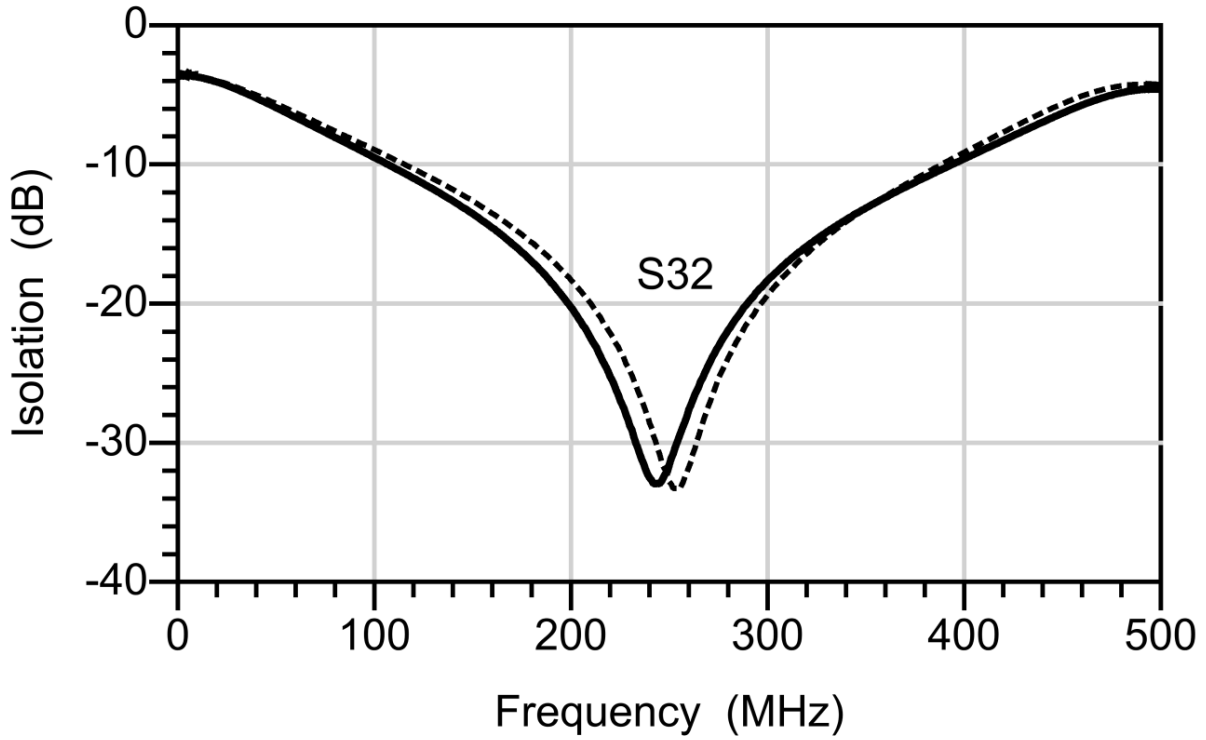




——————— Hybrid Wilkinson device – – – – – – PCB Wilkinson device

Experimental (V)

- EM Characterization.



——————— Hybrid Wilkinson device – – – – – – PCB Wilkinson device

Experimental (VI)

	This work	[1]	[2]	[3]
IL (dB)	3.32	3.25	**3.20**	3.30
IRL (dB)	**36.9**	19.0	36.4	14.0
ORL (dB)	**32.8**	25.6	29.0	22.0
ISO (dB)	**32.7**	26.5	28.4	15.0
f_c (MHz)	250	433	800	800
CFM	**2.91**	2.41	2.38	2.5
Reconf.	++	X	+	+

$$\mathbf{CFM} = \frac{\lambda_c/4}{\mathbf{Max\ length}} = \frac{c/4f_c}{\boldsymbol{Max\ length}}$$

[1] R. Rahardi, M. Rizqi, W. D. Lukito, R. Virginio, M. Hilmi and A. Munir, "Meander Line-based Wilkinson Power Divider for Unmanned Aerial Vehicle Application," *2020 IEEE International Conference on Communication, Networks and Satellite (Comnetsat)*, Batam, Indonesia, 2020, pp. 178-181.

"Meandering"

[2] J. Ning, L. Chen, S. Bu and C. Zeng, "A new design of compact microstrip Wilkinson power dividers," *2014 IEEE International Symposium on Radio-Frequency Integration Technology*, Hefei, China, 2014, pp.1-3

"Reactive loading"

[3] JAMSHIDI, Mohammad Behdad, et al. Size reduction and performance improvement of a microstrip Wilkinson power divider using a hybrid design technique. *Scientific Reports*, 2021, vol. 11, no 1, p. 7773.

"L-C TL segments"

Conclusion (I)

- Practical design of Wilkinson devices in the low RF band using helical-microstrip TL segments has been demonstrated.
- Compatibility of PCB technology and 3D helical-microstrip technology has been verified.
- 75% of area reduction compared to a standard implementation using planar PCB technology.
- Good performance, in terms of losses and isolation, compared to compact Wilkinson devices found in the literature.

Conclusion (II)

- Further work is currently underway to expand the use of helical-microstrip TL technology to other applications in the RF band.

Thank you !