SDC1: Design of a Self-Interference Cancellation Coupler

Sponsoring MTT-S Technical Committees

MTT-4 Microwave Passive Components and Transmission Line Structures
MTT-24 Microwave/mm-Wave Radar, Sensing and Array Systems

Competition Summary

The Self-Interference Cancellation Coupler (SICC) Student Design Competition (SDC) aims to introduce students to microwave passive components as well as microwave system design and is open to all students, both undergraduate and graduate, registered at an educational institution. Competitors are required to design, realize, and demonstrate a self-interference cancellation coupler in the 24 GHz ISM frequency band that will be evaluated regarding input and output matching, insertion loss, isolation, and size.

Competition Motivation

In monostatic continuous wave (CW) radar systems, the radar coupler is an important component as it separates the transmit (Tx) and receive (Rx) signals. This is particularly important in applications that require the highest precision, such as industrial process monitoring or non-contact measurement of human vital signs in medical applications. Poor isolation of the radar coupler restricts the dynamic range and limits the measurement performance. Figure 1 shows an exemplary block diagram of a CW radar system with the green marked radar coupler as one of the key components in the RF circuit part.

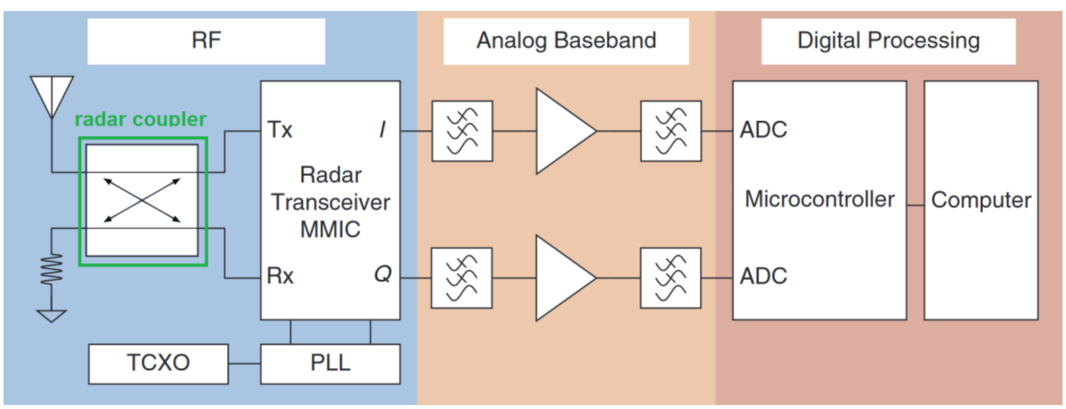

Figure 1: Exemplary block diagram of a monostatic CW radar system (image modified from [1])

In practice, the isolation of the coupler is limited by manufacturing and material tolerances. Furthermore, the bandwidth is limited by the design. Therefore, the goal of this SDC is to design, realize and measure an optimized coupler with additional self-interference cancellation in the 24 GHz ISM frequency band.

Detailed Competition Description

Design goals and measurement setup

The goal of this SDC is to design and realize a self-interference cancellation coupler in the 24 GHz ISM frequency band (ranging from 24 GHz to 24.25 GHz). A simplified block diagram and measurement setup to evaluate the coupler is shown in Fig. 2. The design goals are (among others) to achieve a low attenuation between port 1 (TX) and port 2 ("Antenna"), as well as between P2 ("Antenna") and P3 (RX) while maintaining high isolation between P1 and P3 under two scenarios:

a) With a direct connection of P2 to the Vector Network Analyzer (VNA)
b) Using an additional "antenna emulator" (that will be provided by the SDC organizers) between P2 and the VNA to challenge your self-interference cancellation concept by emulating a realistic (non-ideal) input matching of an antenna in the range of -10dB to -15dB.

Furthermore, the input and output matching as well as the size of the board, are evaluated. The detailed scoring and calculation of the $Score_{total}$ are described in the "Evaluation Criteria" section. The VNA, a calibration kit, and measurement cables with 3.5 mm standard will be provided by the organizers. It is thus recommended to design the PCB with 3.5mm female coaxial connectors.

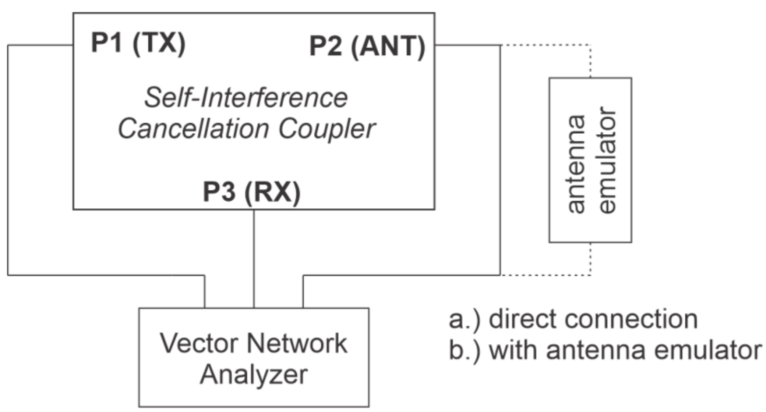

Figure 2: Simplified block diagram and measurement setup to evaluate the self-interference cancellation coupler. The VNA and antenna emulator will be provided by the SDC organizers.

Design possibilities

The fundamental idea of the SICC is to increase the limited isolation of the coupler by combining the parasitic signal with an (at best) opposite phase signal of (at best) equal power, thereby canceling it. There are various possibilities to design an SICC that can be freely developed by the participants as long as they adhere to the competition rules.

Fig. 3 shows two possible design options of an SICC for a better understanding of the competition and for inspiration. Variable attenuators and variable phase shifters are used in this case to generate the negative feedback signal. A power detector at the output measures the result and a microcontroller sets the attenuators and variable phase shifters to the ideal settings. External embedded platforms (such as Arduino) and/or a laptop may also be used for data acquisition and control.

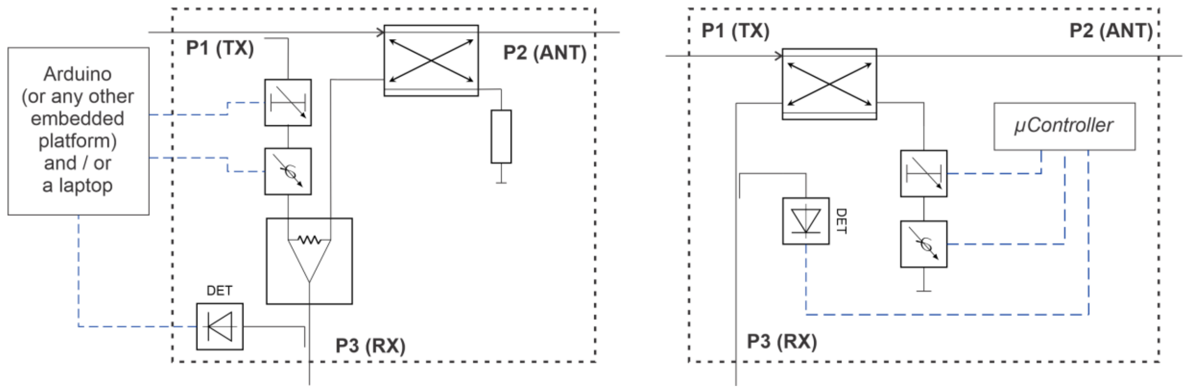

Figure 3 Two possible designs for a better understanding of the competition and for inspiration. All designs that comply with the competition rules are allowed.

Competition Rules and Evaluation Criteria

- As the design goal is to build an optimized self-interference cancellation coupler all coupler(s), divider(s), splitter(s), and combiner(s) are only allowed as self-designed printed circuit board (PCB)-based passive components.
- Circulators may be used but only magnet-free as self-designed PCB-based passive components.
- For all other components (e.g. attenuators, phase shifters, detector, µC, etc.) commercial off-the-shelf (COTS) components are allowed
- No active components (= amplification) are allowed in the transmission path (P1 -> P2) as well as in the receive path (P2 -> P3)
- Active components are allowed in the cancellation path as well as in the detector path
- The SICC of the participants is evaluated in the measurement setup shown in Fig. 2. The VNA and antenna emulator are provided by the SDC organizers as well as a power supply with a single DC voltage output up to 15 V.
- The design is evaluated at 5 frequencies in the 24 GHz ISM frequency band: f = 24.00 GHz, 24.0625 GHz, 24.125 GHz, 24.1875 GHz, and 24.25 GHz at an output power of +10 dBm
- At each frequency point, the SICC has a setting time of up to two minutes after which the S-parameters are read by the organizers on the VNA
- No further interactions are allowed after the start of the measurement. The SICC must find its setting automatically. However, the SICC may be reset between the individual frequency points.
- Trivial solutions that theoretically score points but do not fulfill the basic radar and SICC functionality (e.g., a simple microstrip line between port 1 and 2) will be disqualified. The final decision is up to the organizers.

The total score $\boldsymbol{Score_{total}}$ is composed of several parts:

$$Score_{total} = 5 * Score_{Ssize} + \sum_{f=1}^{5} Score_{S11} + Score_{S22} + Score_{S21} + Score_{S32} + 1.5 * Score_{S31,d} + 1.5 * Score_{S31,e}$$

With a corresponding calculation of the single scores according to:

Description	*Score_*	Min	*Min < Value < Max*	Max
		(0 Points)		(10 Points)
Matching (dB)	***S11***	>= -5	*= -2/3 * (S11 + 5)*	<= -20
	S22	>= -5	*= -2/3 * (S22 + 5)*	<= -20
Insertion Loss (dB)	***S21***	<= -9	*= 5/3 * (S21 + 9)*	>= -3
	S32	<= -9	*= 5/3 * (S32 + 9)*	>= -3
Isolation (dB) - direct	***S31_d***	>= -10	*= -1/3 * (S31 + 10)*	<= -40
Isolation (dB) - emulator	***S31_e***	>= -10	*= -1/3 * (S31 + 10)*	<= -40
Size (cm^2) of the RF board	***size***	>= 100	*= -1/8 * (size - 100)*	<= 16

Thus, a maximum of 400 points can be achieved in best case. The team with the highest $Score_{total}$ wins. In the event of a tie, the team with the lower power consumption of the RF board wins.

Student Eligibility Criteria

The General Rules and Requirements from https://ims-ieee.org/SDC2022 apply for the Student Eligibility Criteria:

1. Teams may consist of 1-4 people.
2. All team members must be full-time students while working on the project.
3. At least one team member must register for IMS2022 and attend the student design competitions on Tuesday, 21 June 2022 in order to assist with measurements (where applicable) and answer questions.
4. You must notify the student design competition organizers at least one week before the date of the competitions if you plan to withdraw or will not be able to participate in person. Failure to participate in person may prevent you from being accepted for future participation.
5. Your professors and advisors must certify that this is your work, not theirs.
6. You must submit a competition application form no later than 10 Mai 2022, or as indicated in the rules of the competition of interest. You are encouraged to contact the coordinators of the competition of your interest as early as possible to ensure a full understanding of the design specifications and judging criteria before your submission.
7. Travel visas and shipping your project equipment are your responsibility.

Awards

The first-place winning team will receive a cash prize of $1000 and will be invited to submit a paper describing his/her project to the IEEE Microwave Magazine. The second- and third- place winning teams will receive a cash prize of $600 and $400, respectively.

Coordinators

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