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Facilitating Antenna Switch Diversity for Dual-Connectivity Architectures

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Abstract:

This publication describes systems and techniques to enable antenna switch diversity in dual-connectivity (DC) architectures without employing two switches along a main antenna path. DC can involve using two different wireless technologies, such as a first technology and a second technology. DC architectures include, for example, those that adhere to the Evolved Universal Terrestrial Radio Access (E-UTRA) – New Radio (NR) — Dual Connectivity (EN-DC) protocol. With EN-DC, Long-Term Evolution (LTE) connections under E-UTRA for a first technology are expected to abide by antenna switch diversity algorithms to provide access to each of the available antennas. Further, Fifth-Generation (5G) connections under NR for a second technology are expected to comport with requirements to use each of the available antennas for Sounding Reference Signal (SRS) transmissions. This disclosure describes including a pair of switches in a switching network that is disposed between multiple antennas and first and second modules of the first and second technologies, respectively. The switch pair is implemented with a crossover switching scheme. A loopback path, which facilitates use of a direct antenna path for the first module, includes two ends. A first end is coupled to one switch of the pair, and a second end is coupled to an auxiliary port of the first module. The second module is coupled to the antennas via the switch pair. The first module, however, is provided a direct path to a main antenna of the antennas. The direct path includes a single switch, which can be part of the first module. In implementations with an example four antennas, the single switch can be realized with a relatively low-loss dual-pole, dual-throw (DPDT) switch in the first module. The switch pair can be realized using two relatively higher-loss four-pole, four-throw (4P4T) switches.

Keywords:

dual connectivity (DC), antenna switch diversity (ASDiv), sounding reference signal (SRS), insertion loss, auxiliary port (AUX port), module, loopback path, low-noise amplifier (LNA) and power amplifier with integrated diplexer (LPAMID), power amplifier with integrated diplexer (PAMID), dual-pole/dual-throw (DPDT) switch, four-pole/four-throw (4P4T) switch, 5G NR, 3GPP LTE, E-UTRA–NR DC (EN-DC)

Background:

A wireless communication device, e.g., user equipment (UE), may be engaged in a dual-connectivity (DC) communication using a first technology and a second technology (e.g., with a first base station and a second base station, respectively). For example, the first technology can correspond to a 3rd Generation Partnership Project Long-Term Evolution (3GPP LTE) wireless network. The second technology can correspond to a Fifth-Generation New Radio (5G NR) wireless network. This type of DC communication may be referred to as Evolved Universal Terrestrial Radio Access (E-UTRA) – New Radio (NR) Dual Connectivity (EN-DC) communication. With EN-DC, LTE connections under E-UTRA are expected to provide access to each of the available antennas to comport with antenna switch diversity (ASDiv) algorithms. Further, 5G connections under NR are expected to have access to each of the available antennas to support SRS requirements.

To enable EN-DC communications, a UE can include a first module corresponding to a first technology and a second module corresponding to a second technology. These two modules are coupled to multiple antennas via a switch network. Each of the multiple antennas may correspond to a different efficiency level. An antenna with a higher efficiency level may be considered the "main antenna." A straightforward approach to meeting both the ASDiv and SRS protocols could include placing a second switch along a main antenna path between the first module and the main antenna or increasing the number of ways in a single-switch scheme.

Certain constraints are imposed on wireless devices if such devices are to properly interoperate with other devices in accordance with a given wireless standard, such as 4G LTE and/or 5G NR. For example, conventional antenna-swapping algorithms require a receive chain to "trade places" with a transmit chain regarding an antenna that is being used by the transmit chain in a passthrough state prior to the antenna swapping. Additionally, EN-DC and other simultaneous architectures operate at a higher performance level if different transmitters of the different technologies occupy different switches to avoid intermodulation desensing. This also implies that a crossover switching scheme could be implemented to handle the potential desensing.

For clarity, aspects of a 4G LTE connection are discussed for the first technology, and aspects of a 5G NR connection are discussed for the second technology. However, one or both of the first and second technologies can be implemented using different standards, specifications, and/or protocols. Also, for simplicity of explanation, some of the description herein is provided in terms of a device with four antennas. However, the described systems and techniques are applicable to devices with a different number of antennas. Consider an example scenario with a 4G LTE connection, a 5G NR connection, and four antennas in a given UE. In this example, 4-way ASDiv for the 4G LTE connection mandates access to the four antennas by a 4G LTE transceiver. To support the 5G NR connection, the UE is also responsible for enabling a 5G NR transmitter to access the four antennas to implement SRS. Addressing these joint ASDiv and SRS obligations could result in utilizing 4-way switching schemes that add more loss to a primary transceiver path as compared to a traditional two-way crossover antenna switching scheme that has a relatively-lower insertion loss.

Therefore, it is desirable to utilize a switching scheme that maintains the same insertion loss as a two-way switch yet nevertheless enables support of both SRS for a 5G NR connection and 4-way ASDiv for a 4G LTE connection.

Description:

This publication describes systems and techniques for enabling a UE to satisfy both SRS and ASDiv obligations for dual-connectivityenvironments while maintaining insertion loss. The UE includes multiple antennas, a first module corresponding to a first technology, a second module corresponding to a second technology, and a switch network, which includes a switch pair. The switch pair is implemented with a crossover switching scheme. The switch network is coupled between the multiple antennas and the first and second modules. The multiple antennas include a "main antenna" with greater efficiency as compared to one or more other antennas of the multiple antennas. The first module includes an auxiliary port and can be operatively coupled to the main antenna without using the switch pair. To do so, a described switching scheme employs a loopback path that establishes an additional routing between the first module and a non-main antenna.

This loopback path has two ends. A first end of the loopback path is coupled to a switch of the switch pair, and a second end is coupled to the auxiliary port of the first module. The second module is coupled to the multiple antennas via the switch pair. A path between the main antenna and the first module can include a single switch because the first module has a direct path to at least the main antenna that avoids the switch pair. This single switch can be disposed in the first module. In implementations with four antennas, the single switch can be realized with a relatively low-loss dual-pole, dual-throw (DPDT) switch located in the first module. The switch pair can be realized using two relatively higher-loss four-pole, four-throw (4P4T) switches with a crossover switching scheme. This switch pair is not disposed along the main antenna path for the transmitter/receiver of the first technology. In these manners, the loopback path can enable SRS and 4-way ASDiv functionalities in DC environments without increasing the insertion loss on at least the main antenna path.

Fig. 1 below illustrates an example UE that can include a switch network with a loopback path. The UE is depicted as a smartphone; however, aspects described herein can be implemented in various types of UEs, such as tablets, wearable devices, laptops, Internet of Things (IoTs) devices, and so forth. As shown, the UE includes four antennas: a first antenna (Ant1), a second antenna (Ant2), a third antenna (Ant3), and a fourth antenna (Ant4). Although an example set of multiple antennas is shown in Fig. 1, antennas may be of different sizes, disposed at different positions of a UE, have a different quantity, and so forth. Each of the antennas may correspond to a different efficiency level. An antenna that has a higher efficiency level as compared to one or more other antennas is referred to herein as a "main antenna." In the examples described herein, the first antenna (Ant1) is the main antenna.

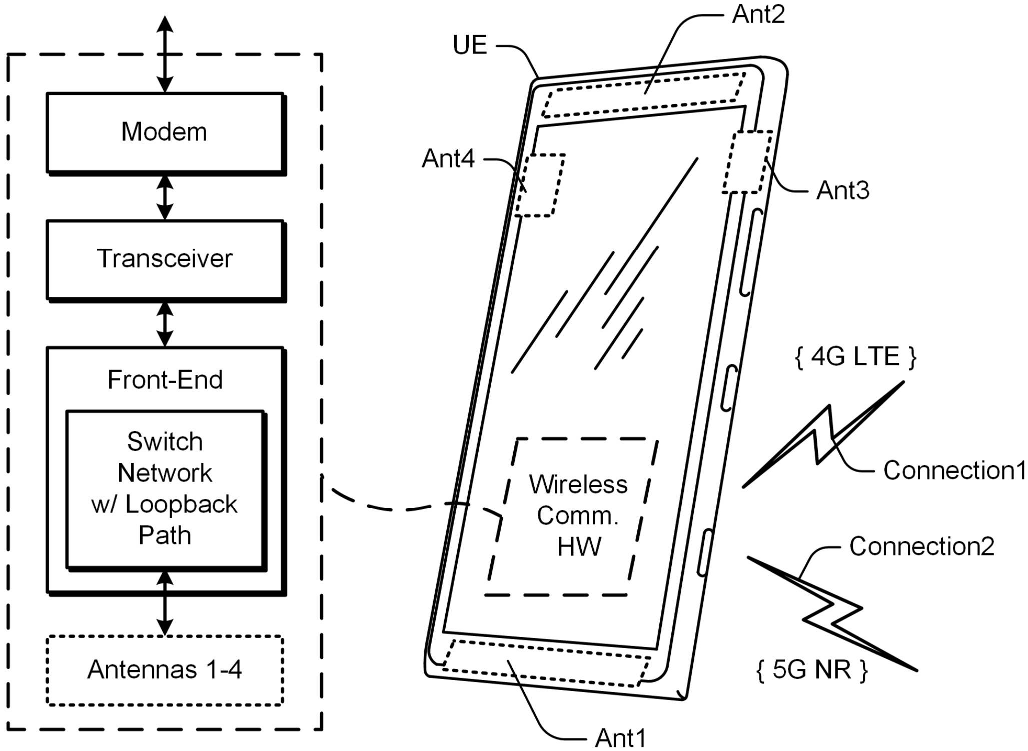

Fig. 1

As shown, the UE includes wireless communication hardware (HW). The wireless communication hardware includes a modem, a transceiver, a front-end, and four antennas. The modem is coupled to other parts of the UE, such as an application processor (not shown). The modem is also coupled to the transceiver, and the transceiver is coupled to the front-end. The front-end includes a switch network having a loopback path. The front-end is coupled to the four antennas via the switch network. The front-end is depicted in greater detail in Fig. 2 below. In operation, the modem can use the transceiver and the front-end to communicate in a DC environment. A first connection (Connection1) can correspond to a 4G LTE technology, and a second connection (Connection2) can correspond to a 5G NR technology.

Fig. 2 schematically illustrates four antennas (Ant 1-4) and the front-end of Fig. 1. The front-end includes a switch network, a first module (Mod 1), a second module (Mod 2), and a loopback path. The switch network includes a switch pair, and the first module includes an auxiliary port (AUX Port). The first module corresponds to the first technology (Tech 1) and is coupled to a transceiver (TRX0) (not shown) of the first technology. The second module corresponds to the second technology (Tech 2) and is coupled to a transceiver (TRX) (not shown) of the second technology.

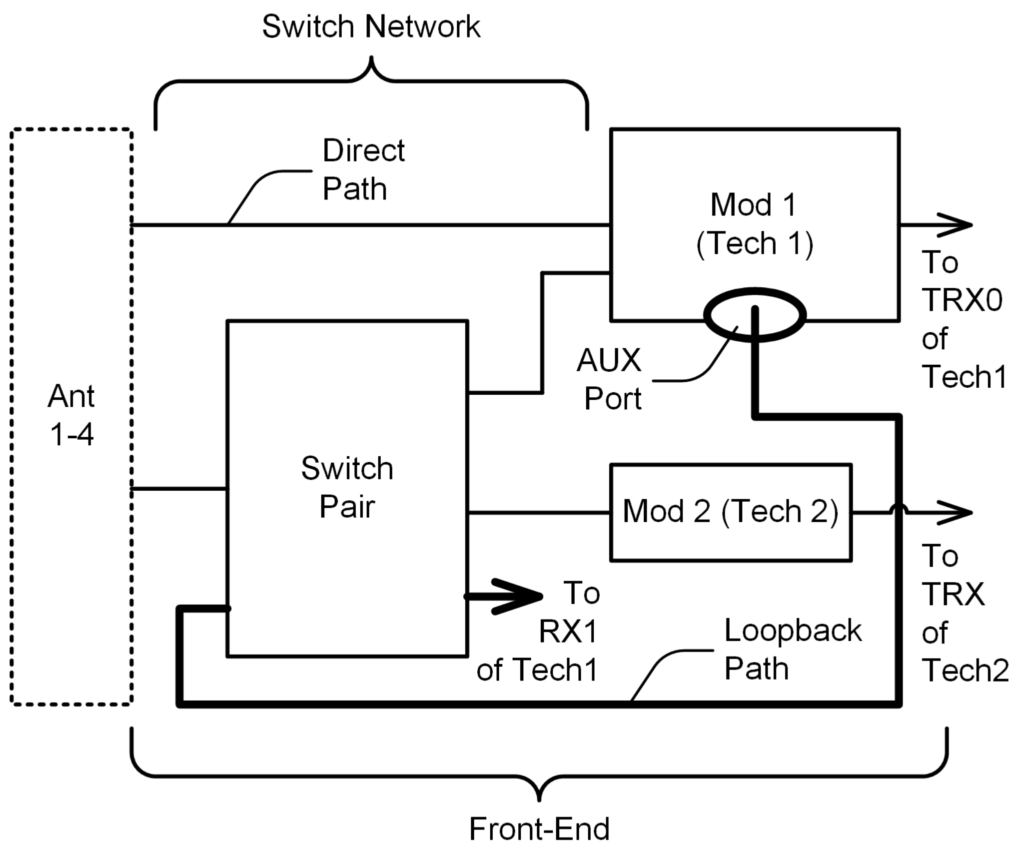

Fig. 2

Generally, the first module and the second module are coupled to the multiple antennas via the switch network. More specifically, the first module is coupled to the multiple antennas via a direct path and the switch pair. The second module is coupled to the multiple antennas via the switch pair. The loopback path is coupled between the switch pair (e.g., an output of the switch pair) and the AUX port of the first module. As described below, the loopback path enables the presence of the direct path for communications of the first technology via the first module while still enabling both SRS for 5G NR and ASDiv for 4G LTE.

Figs. 3, 4, and 5 respectively depict the first module, the second module, and the switch pair. Fig. 6 illustrates the system, including the loopback path. A description of the system below provides example signal propagation paths to enable SRS and ASDiv for each of the four antennas.

Fig. 3 below illustrates an example first module for transmit and receive communications with the first technology (Tech1). The first module includes a diplexer, an antenna switch module (ASM), a first port (Port1), a second port (Port2), and the AUX port. The diplexer is coupled to a transmitter (TX0) and a receiver (RX0) of the first technology. The diplexer can include, for instance, one or more filters. The diplexer and the AUX port are coupled to an "internal" side of the ASM. The first and second ports are coupled to an "external" side of the ASM.

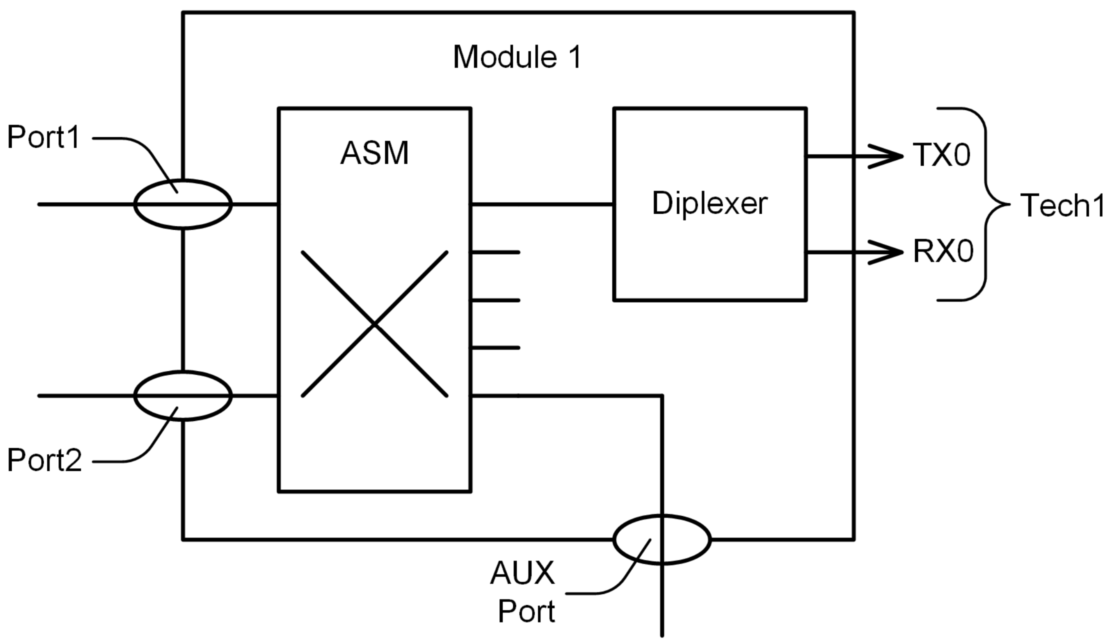

Fig. 3

Some modules (e.g., a low-noise amplifier (LNA) and power amplifier with integrated diplexer (LPAMID) or a power amplifier with integrated diplexer (PAMID)) include a DPnT switch with an AUX port. The ASM provides internal technology paths that have access to an antenna passthrough path (via Port1 and the direct path) and an antenna crossover path (via Port2 and the switch pair), which are depicted in Figs. 2, 3, and 6. Thus, with the ASM, signals of the first technology can access Port1 or Port2, and signals of the AUX port can access Port2 or Port1 correspondingly and at different times.

Fig. 4 below illustrates an example second module for transmit and receive communications with the second technology (Tech2). The second module includes an amplifier, a diplexer, and a port, which is labeled as a third port (Port3) of the system depicted in Fig. 6. The amplifier is coupled to a transmitter (TX) of the second technology. The diplexer is coupled to an amplified version of the transmit signal and a receiver (RX) of the second technology. The diplexer is coupled to the third port (Port3).

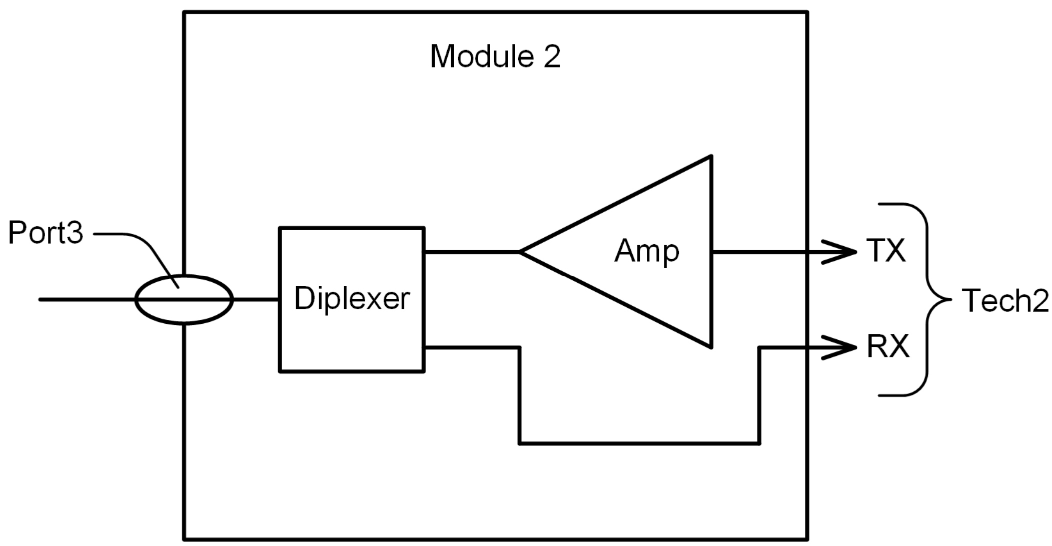

Fig. 4

Fig. 5 below depicts the switch pair, which includes a Switch A and a Switch B. The two switches are realized as 4P4T switches; each switch therefore has eight total pins. Of the eight pins, each switch includes four pins 1–4 on one side and four pins 5–8 on the other side. Any pin on one side of a given switch can be operatively coupled to any pin on the other side. Further, as shown, the two 4P4T switches are arranged in a crossover scheme with a crossover path A (CO Path A) and a crossover path B (CO Path B). Crossover path A is coupled between Pin8 of Switch A and Pin1 of Switch B. Crossover path B extends between Pin5 of Switch B and Pin4 of Switch A. Thus, the crossover scheme provides access from pins 1,2,3,4 of Switch A to pins 5,6,7,8 of Switch B via the crossover path A. Similarly, the crossover scheme provides access from pins 1,2,3,4 of Switch B to pins 5,6,7,8 of Switch A via the crossover path B.

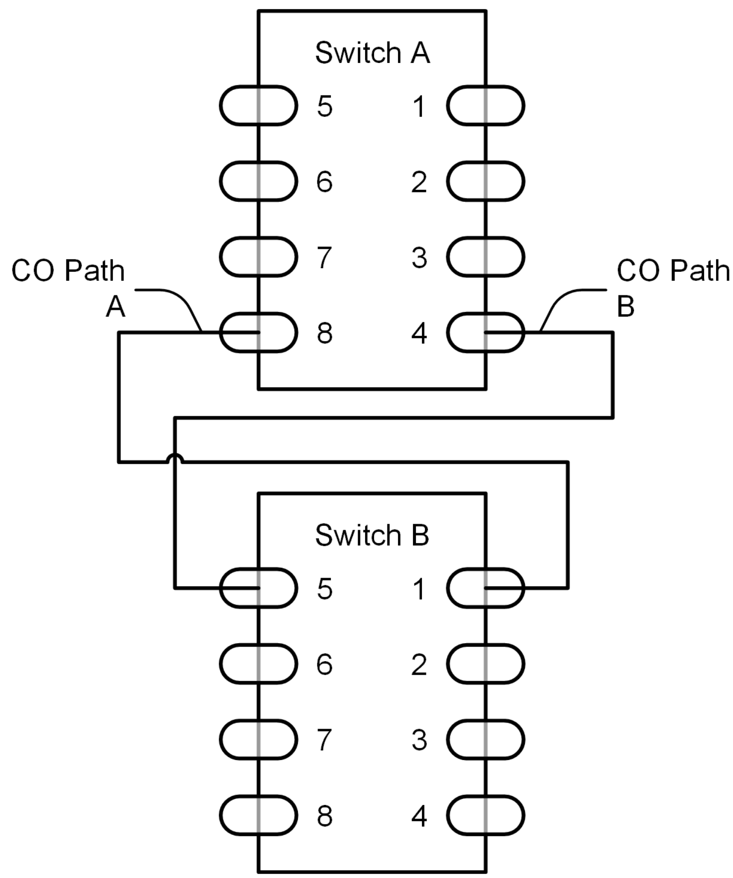

Fig. 5

Fig. 6 below depicts an example system of modules and switches with four antennas and a loopback path. As shown, Port1 is coupled to Ant1 to establish a direct path for the main antenna for the first technology of the first module. Port2 is coupled to Pin1 of Switch A, and Pin5 of Switch A is coupled to Ant2. This provides a path between the first module and Ant2. Port3 is coupled to Pin2 of Switch B. Pin6 of Switch B is coupled to Ant3, and Pin7 of Switch B is coupled to Ant4. These connections provide paths between the second module and both Ant3 and Ant4. The loopback path is coupled between Pin8 of Switch B and the AUX port of the first module. To enable use of the loopback path with the first technology, Pin4 of Switch B is coupled to another transceiver of the first technology (e.g., another receiver (RX1) corresponding to Tech 1).

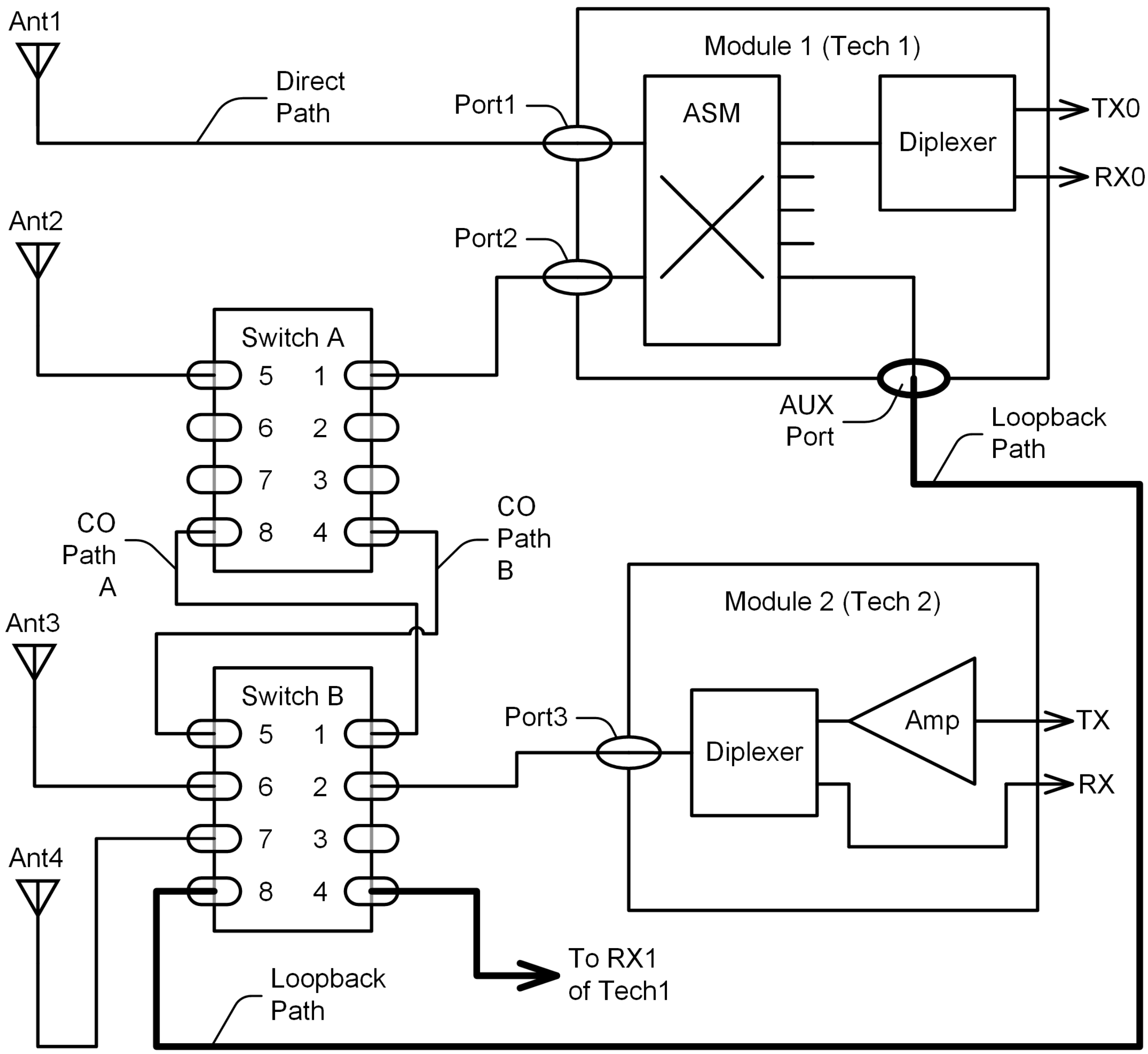

Fig. 6

ASDiv for the first technology (Tech1) can be realized as follows. In a passthrough mode:

TX0/RX0 are mapped to Port1 of Module 1 (using the ASM) → Ant1; and

RX1 is mapped to Pin4 of Switch B → Pin7 of Switch B → Ant4.

In a crossover mode:

TX0/RX0 are mapped to Port2 of Module 1 (using the ASM) → Pin1 of Switch A → Pin8 of Switch A → Pin1 of Switch B → Pin7 of Switch B → Ant4; and

RX1 is mapped to Pin4 of Switch B → Pin8 of Switch B → AUX Port of Module 1 (via the loopback path) → Port1 of Module 1 (using the ASM) → Ant1.

This scheme is therefore compliant with the antenna switch algorithm in which, after a crossover between RX1 and TX0, RX1 of Tech1 has swapped antennas with the one that TX0 was using prior to the crossover. In other words, RX1 of Tech1 can be switched to Ant1 after the crossover.

SRS for the second technology (Tech2) can be realized as follows:

TX mapped to Port3 → Pin2 of Switch B → Pin6 of Switch B → Ant3;

TX mapped to Port3 → Pin2 of Switch B → Pin7 of Switch B → Ant4;

TX mapped to Port3 → Pin2 of Switch B → Pin5 of Switch B → Pin4 of Switch A → Pin5 of Switch A → Ant2; and

TX mapped to Port3 → Pin2 of Switch B → Pin8 of Switch B → AUX Port of Module 1 (via the loopback path) → Port1 of Module 1 (using the ASM) → Ant1.

Thus, this scheme also provides Tech2 with access to each of the four antennas for SRS.

References:

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