



Air Interface Emulators

An overview of the systems from
MTS Systemtechnik GmbH

Individual high-frequency technology



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// Content



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// About MTS Systemtechnik

Tailored solutions for high frequency technology, EMC, electronics and mechanical design

Our customers include developers and manufacturers of highly sensitive equipment in the mobile communications, telecommunications, aerospace, defence, medical, automotive and electronics sector. Our devices, systems and components are used worldwide by leading international companies.

For over 30 years, MTS Systemtechnik has stood for state-of-the-art technology, outstanding reliability, discretion, transparent processes and certified quality in accordance with DIN EN ISO 9001.

With around 50 employees, we develop and manufacture bespoke, high-quality devices, systems and components – Made in Germany – as well as customer-specific products.

Our electronic product range includes coaxial relays, attenuators, power splitters, systems for the distribution of LF, video and RF signals, RF matrices and assembled coaxial cables. Our expertise in solving complex switching and distribution tasks in the high-frequency range has made us a leading manufacturer of relay switching units, air interface emulators, power splitter units and matrices.

For the mobile radio and telecommunications industry, we supply customised shielding boxes, air interface emulators for a wide range of test scenarios, and smart antenna simulators.

With our modern CNC production centre, we manufacture customer-specific precision-milled parts for the aerospace, optical and high-frequency industries.

The distribution of coaxial connectors from IMS Connectors and the assembly of coaxial cables complete our product range.



Systems for the distribution of LF, video and RF signals in the fields of tele- and satellite communication and radio surveillance



Production of mechanical components for the aerospace, optical and high-frequency industries



Development and production of active and passive components for high frequency technology

// Introduction

Air-interface emulators such as the Air Interface Adapter (AIAD) and Standard Coupling Field (SCF) from MTS Systemtechnik enable mobile-radio base stations and mobile stations to be tested in the lab via the air interface. Reproducible RF tests can be carried out independently of environmental radio interference by using emulators, cables and shielding boxes.

Engineers are able to efficiently emulate a wide variety of specific wireless-network handover scenarios. The MTS air-interface emulators were designed for mobile-radio testing from 2G up to 5G FR1, but can also be used for Wi-Fi, Bluetooth and other radio technologies (e.g. TETRA).

How does it work?

Semiconductor switches selectively insert attenuator stages of 1 dB, 2 dB, 4 dB, 8 dB, etc. into the signal path, allowing any attenuation value from 0 to 95 dB in 1 dB increments. Step sizes of 0.5 dB or 0.25 dB are available on request. An integrated control logic selects the required attenuation stages.

The programmable attenuators transmit RF signals bidirectionally; the uplink and downlink therefore have the same attenuation. Internal attenuation switching is continuous and interruption-free. Several programmable attenuators, together with signal splitters and combiners, are integrated into the AIAD to emulate the radio field by means of an attenuation network. The system is controlled via various interfaces, including LAN, USB and RS-232, using SCPI-compatible command strings.

A Windows application for quickly programming ramps for handover tests is available as an accessory.



What tests can be performed?

- // Different mobile-radio handover test scenarios are possible, including inter-cell and inter-system handovers. The switching time is less than 10 ms; a TTL version with a switching time of 50 μ s is also available.
- // Injection of an interference source, for example for bit-error-rate tests.
- // Tests in a live network using portable Frequency-Selective Attenuation Network (FSAN) models (see the “Other Air-Interface Emulators” chapter below).

// Description

AIAD-X/Y (X/Y = number of inputs/outputs)

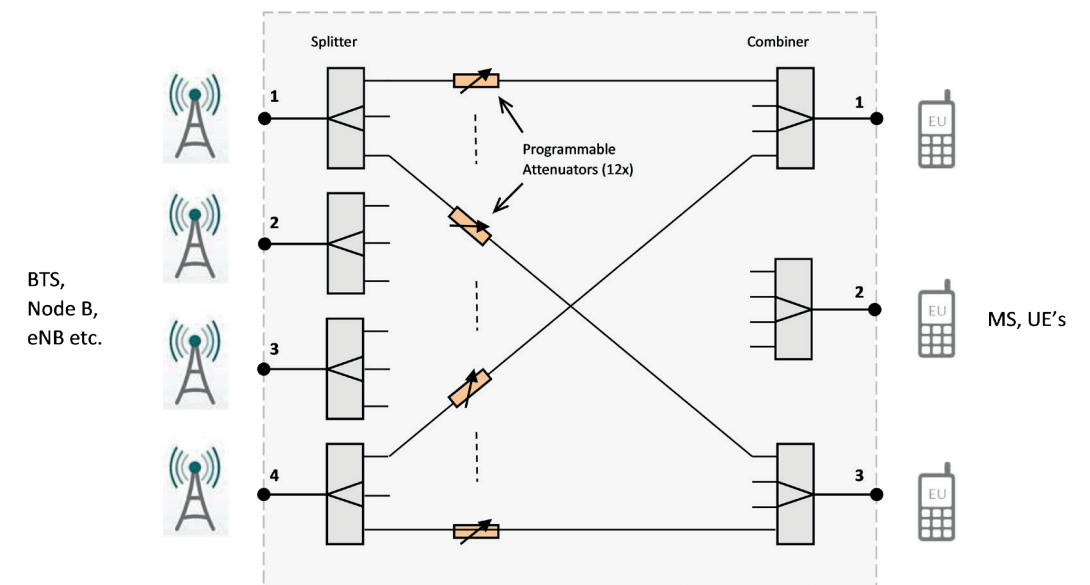
A number of programmable attenuators are combined into a single matrix (full fan-in / full fan-out attenuation matrix) to emulate different air-interface radio conditions.

The AIAD is connected on one side to various base-station signals (BTS, NodeB, eNB or gNB) and on the other side to a number of mobile devices (MS or UE). If the mobile devices have no RF connector, they should be placed in separate shielding boxes (also available from MTS Systemtechnik) and each connected via an antenna (accessory). This enables tests without environmental radio interference. The desired attenuation values can be set individually for each path between base stations and mobile devices. Adjustments can be made remotely via LAN or USB interfaces. Manual control via a touch-panel display is available on request.

- // Robust design thanks to solid-state switched attenuation
- // No calibration required
- // Frequency range: 400 MHz to 8000 MHz



Block diagram, example AIAD-4/3:



SCF-0350-4G / SCF-360-6G

The SCF-03xx series can be used for GSM, UMTS, LTE and 5G frequency ranges up to 4 GHz, additionally covering most 5G FR1 bands.

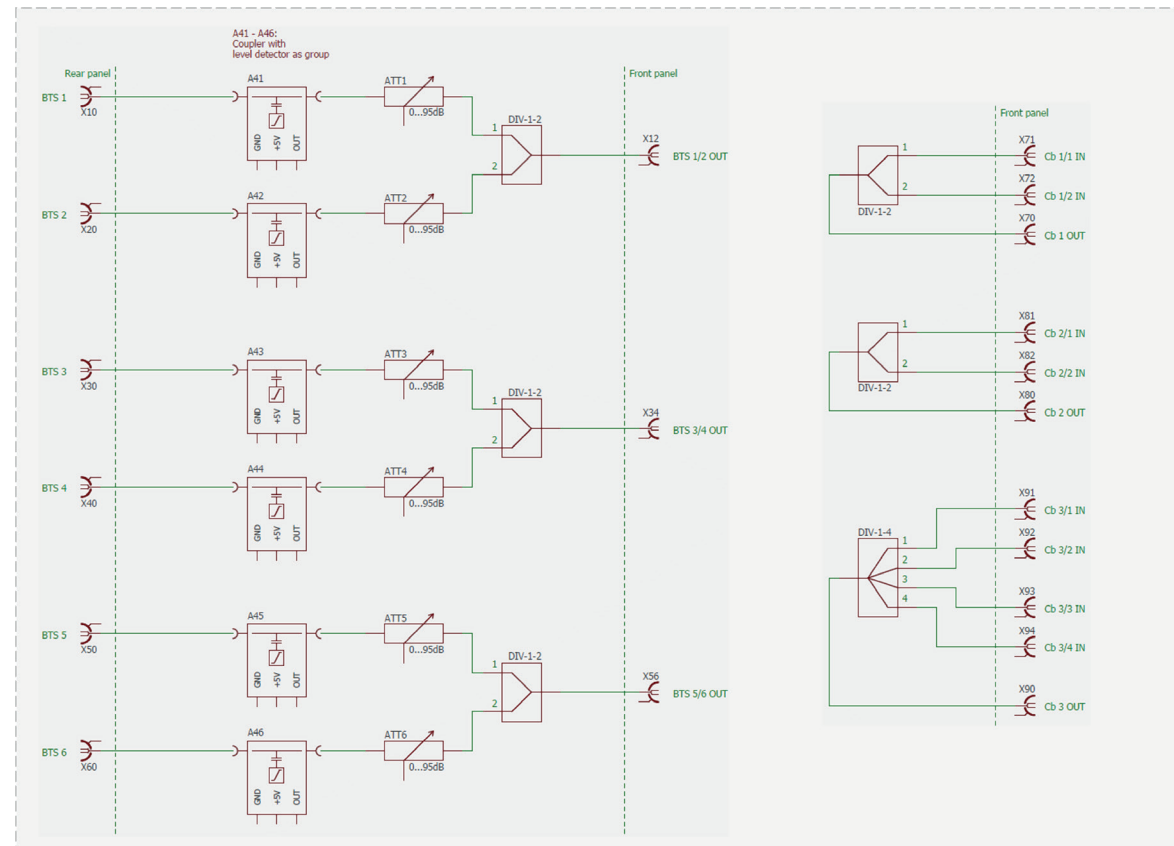
Two BTS, NodeB, eNB or gNB input signals can be attenuated separately using programmable attenuators and are combined to a single output connector (BTS x/y OUT). The MS or UE is connected to this output connector. If the MS or UE has no RF connector, it can be operated inside an MTS Systemtechnik shielding box (MSB series) and connected via an antenna (accessory), thereby enabling tests without environmental radio interference.

For each input connector (BTS1 to BTS6), a level detector distinguishes between two signal-power threshold levels. A green LED illuminates if the signal is within the range of -40 dBm to +15 dBm; a red LED illuminates if it exceeds +15 dBm and is potentially too high.

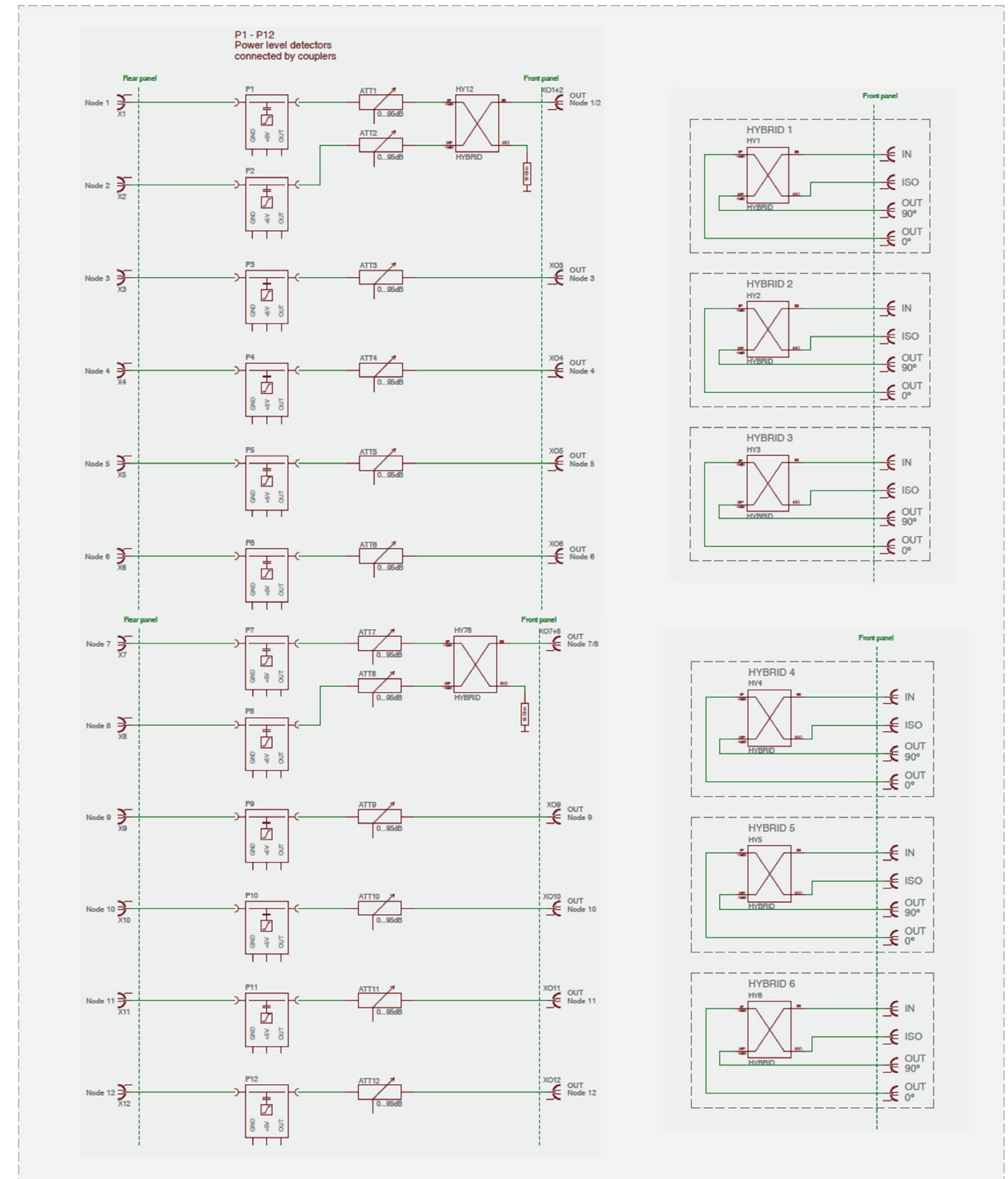
As shown in the block diagram below, the SCF-03xx device incorporates a total of three 2:1 programmable-attenuator stages as described above. The additional power splitters (2 × 1:2 and 1 × 1:4) on the right side of the block diagram can be used as required for further signal combining or distribution.

- // Robust design thanks to solid-state switched attenuation
- // No calibration required

Block diagram, SCF-0300/SCF-0350-4G:



Block diagram, SCF-0600/SCF-0601:



SCF-0600-6G / SCF-0601-6G

This device covers the frequency range from 700 MHz to 6 GHz, thereby supporting 5G FR1 and the Wi-Fi 5 GHz band.

The SCF-0600-6G is an extended SCF variant offering more signal paths, a greatly expanded frequency range and higher input power. It emulates air interfaces between 12 input connectors and 10 output connectors. Each signal path can be attenuated individually using programmable attenuators. For each input connector, a level detector distinguishes between two signal-power threshold levels. A green LED illuminates if the signal is within the range of -45 dBm to $+10$ dBm; a red LED indicates potentially excessive power above $+10$ dBm. (The threshold levels for the SCF-0601 are -40 dBm and $+15$ dBm.)

The desired attenuation values can be set via manual control (up/down buttons and display) or remotely via RS-232, LAN and USB interfaces. The integrated RK3 hybrid couplers (3 dB couplers) can be used as required for further signal combining or distribution. See below for further details and schematics.

- // Robust design thanks to solid-state switched attenuation
- // No calibration required

Possible Testing Problems

The test environment of air interface emulators usually consists of a number of base stations and mobile stations in order to reproduce test scenarios under laboratory conditions. By means of shielding boxes, the mobile devices can be protected from radio interference from the surrounding area. The RF signals are distributed via coaxial cables. Everything seems safe — nevertheless, problems can still arise due to the test layout. In order to maintain the air interface even under difficult conditions, mobile radio systems have a very large link budget.

Example of the GSM power margin (without taking the TX antenna gain into account):
 Maximum output power of a BTS (approx.): +45 dBm
 Sensitivity of a mobile device (approx.): –105 dBm
 Maximum power margin: **150 dB!**

This corresponds to a power ratio of 1 : 1 quadrillion (1 : 10¹⁵). If we consider other radio technologies, such as IoT, the link budget is even considerably higher!

The following risks may arise:

- // Interference in the surrounding area caused by signals leaking through the shield of the RF cables connected to the base station (cable shielding is normally ≤ 100 dB).
- // Reduced shielding of the device under test (e.g. due to poorly screened USB or RS-232 cables in combination with the shielding box).

Solution:

The output signal of a base station should never be routed via coaxial cables at such high power. This can easily be avoided by using high-power fixed attenuators that have to be screwed directly onto all RF connectors of each base station. For this purpose, 30 dB, 50 W fixed coaxial attenuators have proved their worth.

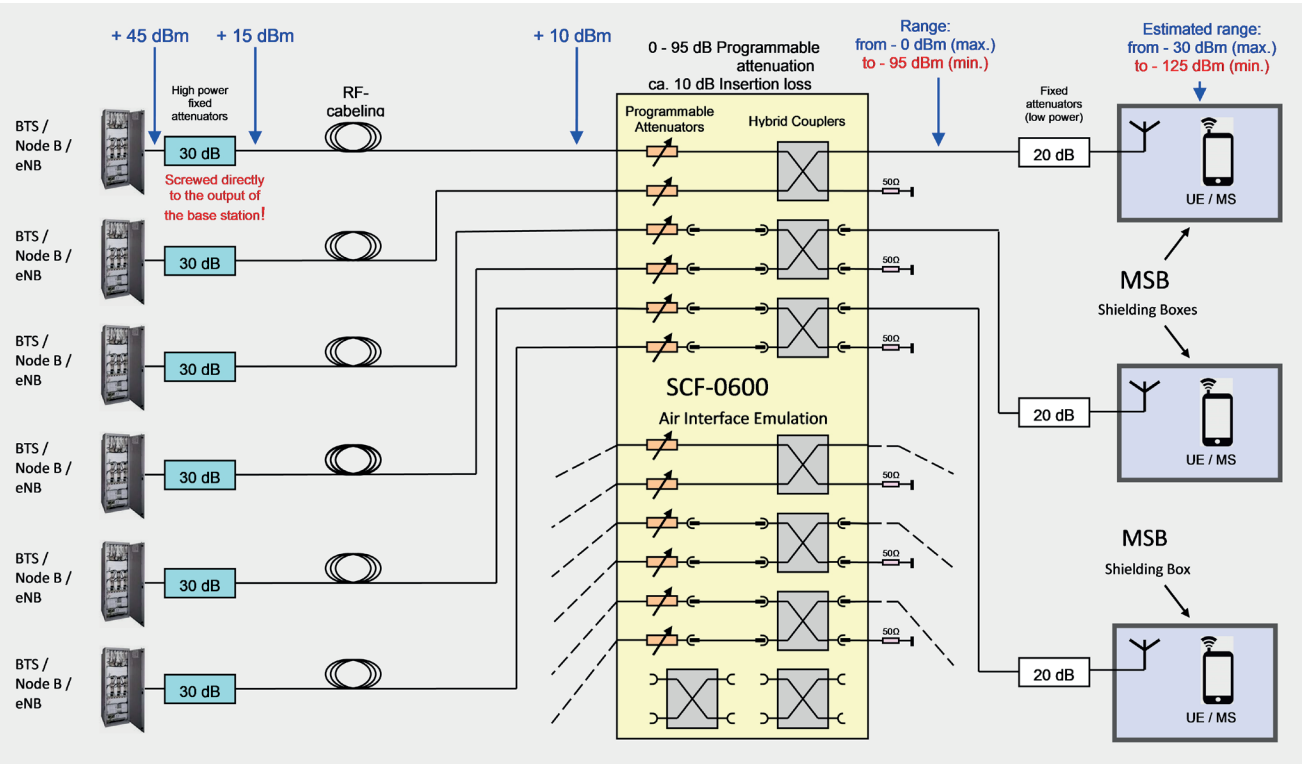
Welcome side effects:

- // The 30 dB fixed attenuators also prevent the maximum input power of the SCF device from being exceeded.
- // In order to suppress radio reception in the mobile device, it is in any case necessary to insert additional attenuation into the signal path, since the SCF alone can not achieve a total attenuation of 150 dB.

SCF total attenuation = set attenuation + insertion loss of the SCF

The 30 dB pre-attenuation reduces the signals sufficiently. A rough calculation of the power levels is shown in the following example.

Typical dimensioning of a Testlab with SCF-0600



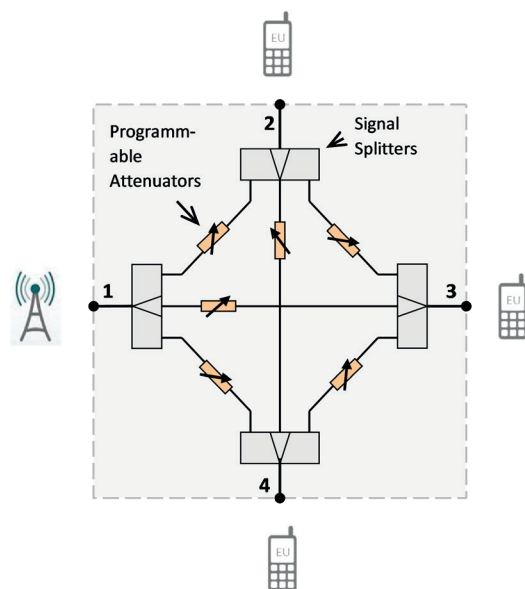
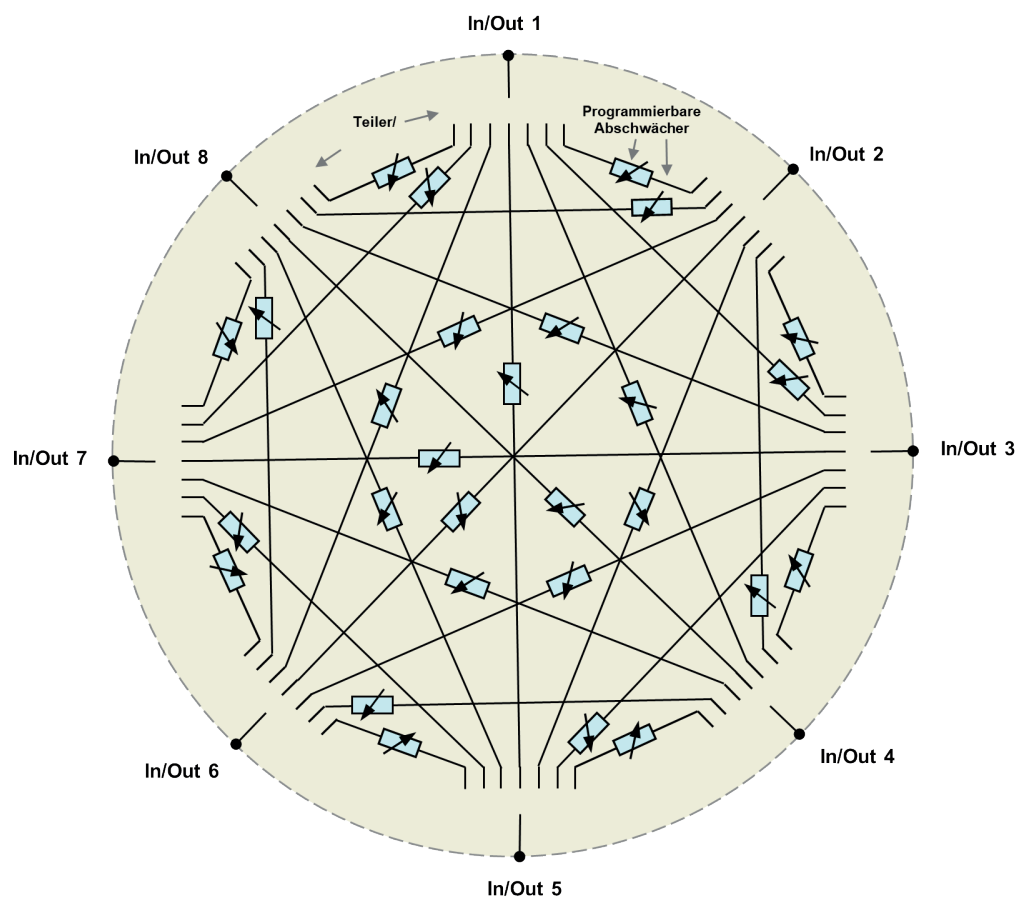
AIAD-X+ (X = number of ports)

This extended topology with fully cross-linked RF ports is required, for example, to test direct mode operation between terrestrial trunked radio (TETRA) stations.

What does ‘fully meshed network’ mean?

Explained using the example of the AIAD-8+:

- A circular RF matrix in its maximum configuration, resulting in:
 - // No blocking, i.e. every RF port can be connected to any other RF port (full fan-in / full fan-out principle).
 - // All RF connections are equivalent.
 - // Different air interface conditions can be simulated freely.
 - // To this end, the desired attenuation values can be set individually for each signal path across up to eight connected radio units.
 - // In total, 28 different attenuation values can be set on an AIAD-8+ system.



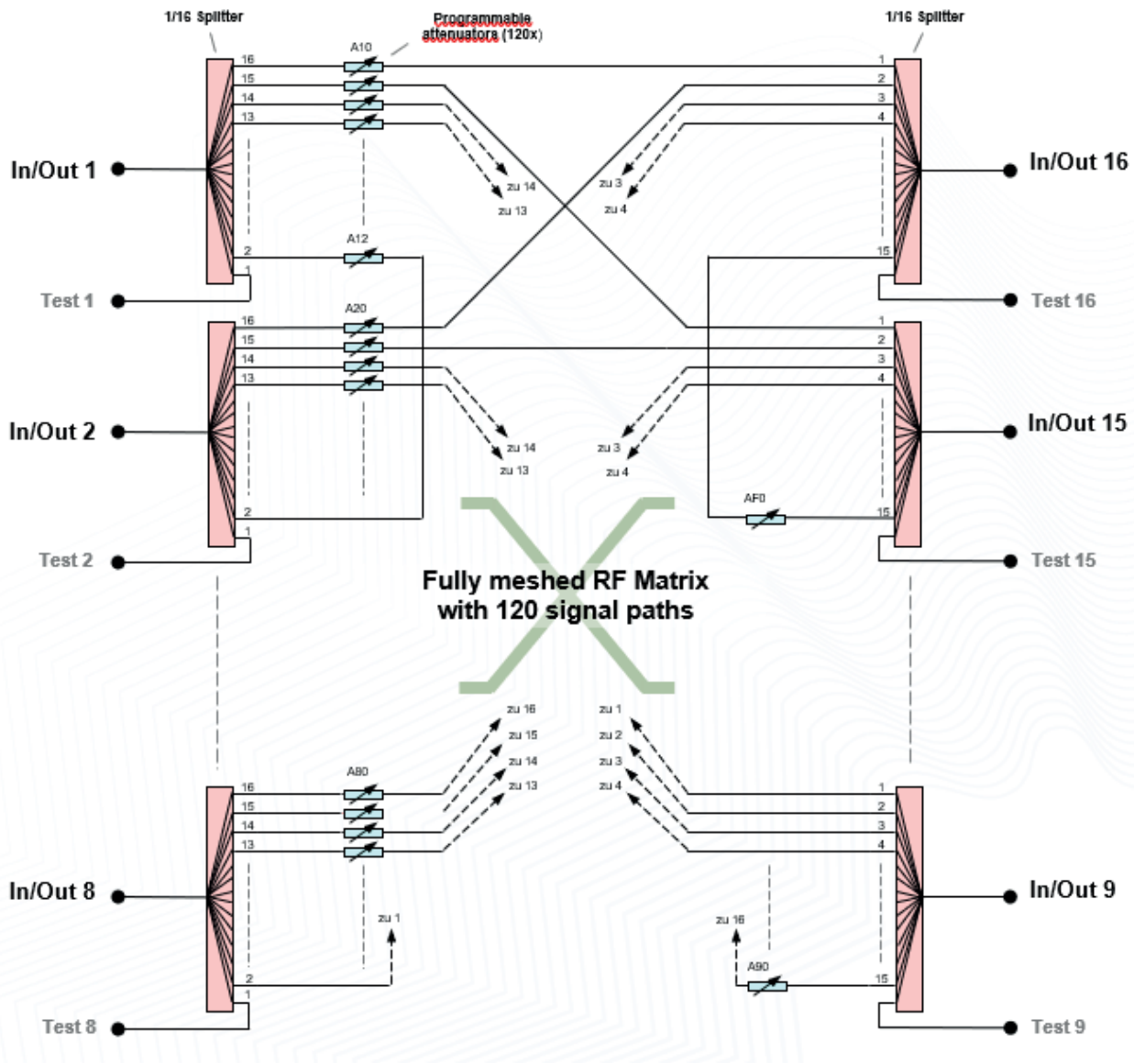
Description of the AIAD-16+-S2 radio field simulator

- // A larger, fully meshed system suitable for up to 16 radio units.
- // A total of 120 programmable attenuators are interconnected in a loop system to form an attenuation matrix with 16 equivalent RF ports, allowing different air interface conditions to be freely simulated.
- // The desired attenuation values can also be set separately for any signal path between the connected radio units, within a range of 0–85 dB.
- // The selected attenuation in a path always has the same effect in both the transmit and receive directions.
- // Switching between attenuation levels is seamless and takes place continuously.
- // A test output is provided on the front panel for each RF connection (although in training centres this is used exclusively for maintenance purposes).
- // The radio field simulator can be controlled via the LAN and USB interfaces.

Using the easy-to-program Windows application ‘Device Control’ (available as an accessory), sequences can be created for all 120 signal paths. This makes it possible to simulate movements in the field, in the form of an attenuation profile, for the connected radio units. When a programmed sequence is started, the calculated attenuation values are sent to the radio field simulator via the interface at one-second intervals and take effect for all connected radio units.



Block diagram of the AIAD-16+-S2 radio field simulator:
The AIAD-16+-S2 is also a circular system; however, due to the large number of components, it can only be shown here in a simplified form!



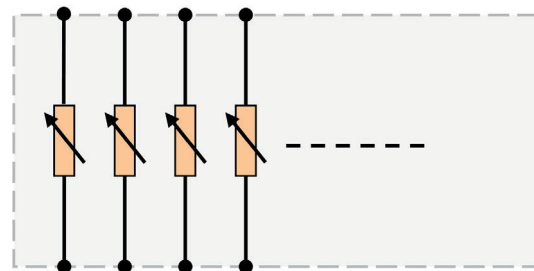
// Other Air Interface Emulators

FSAN, Frequency Selective Attenuation Network

An antenna signal is split into several frequency ranges by multiplex filters, attenuated separately by programmable attenuators and then recombined by a second multiplex filter to form a single signal. The FSAN can be used for inter-system handover tests. Portable versions of the FSAN can be built for drive tests in live mobile radio networks.

PAH-X, Programmable Attenuator Unit

(X = number of paths) Several programmable attenuators are integrated in a single device. All connections are accessible from the front or rear panel. These units usually feature built-in manual control.

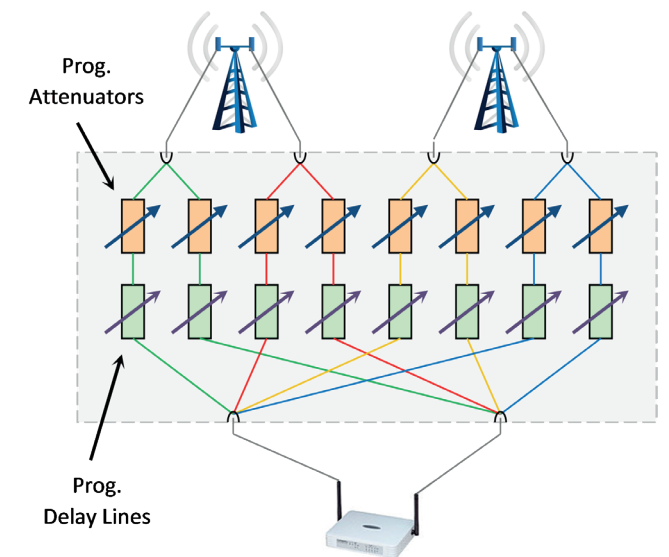


AIAD with Extended Accuracy

Higher attenuation accuracy can be achieved by calibrating the device to a narrow frequency range.

MIMO-Tester

This device is suitable both for emulating antenna diversity and for beamforming. It can be used for HSPA+, LTE and Wi-Fi tests. The channel matrix is emulated by means of attenuators and delay lines, each of which can be digitally adjusted. The attenuation of each channel can be set over a range of 0 to 95 dB in 1 dB steps (0.5 dB or 0.25 dB steps available on request). Phase differences between individual channels can also be emulated by means of corresponding time delays of up to 1,600 picoseconds (ps).



SAS, Smart Antenna System Adapter

Emulation of beamforming by programmable delay lines for WiMAX. It is also used for MIMO.

