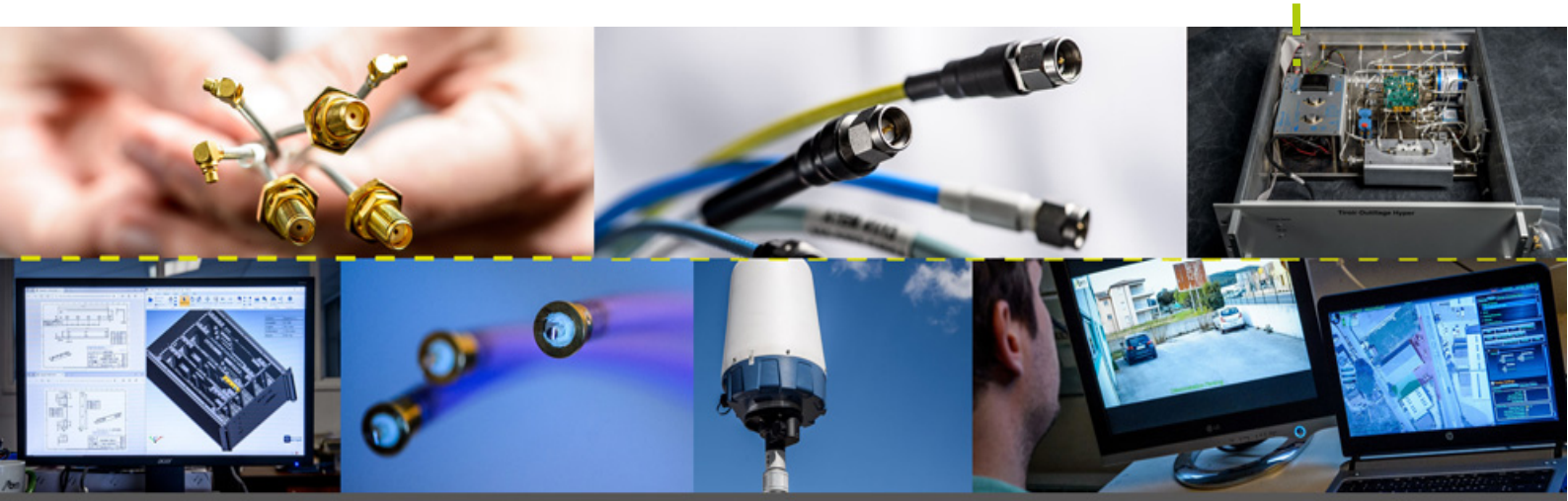
ATEM customized connectivity	**Technical Paper n°1**	05/01/21 **6 pages**

Technical Paper

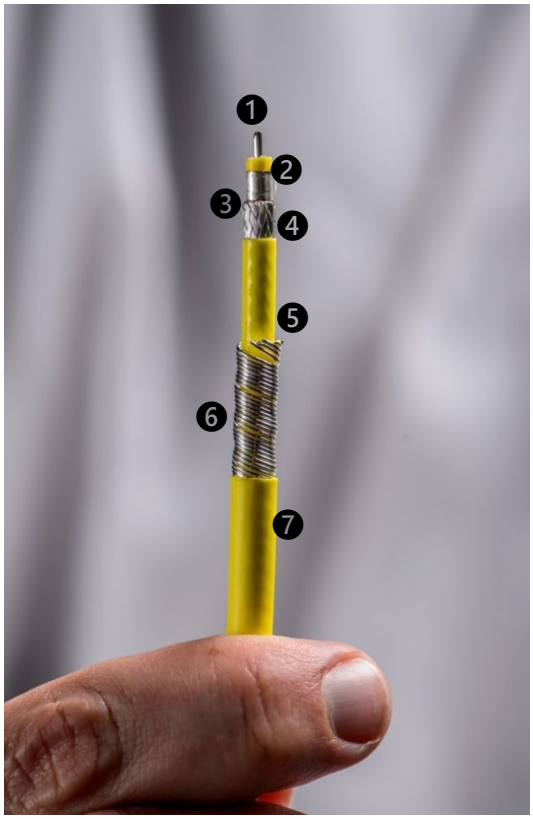
RF & Microwave interconnection solutions: how to determine your coax cable assemblies for your specifc applications ?



ATEM customized connectivity

Definition, Manufacturing, Test & Measure

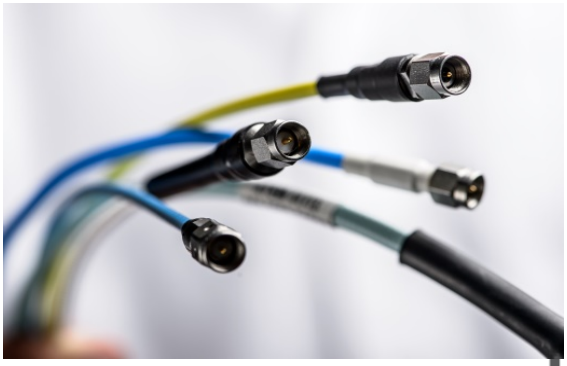
The coax cable assembly is a link which makes the transmission of an electromagnetic signal between 2 devices possible. It consists of one cable and two connectors at each end of the coax cable.
The coax cable assembly is defined by the following main elements:



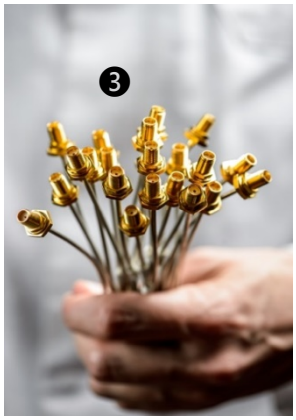
- Central core ❶: it can be single-braid (more rigid, less losses) or multi-braids (more flexible, more losses). This is the conductive part of the signal. It is generally made of copper, silver-plated copper, or even copper-plated steel.
- Insulator ❷: dielectric material surrounding the central core. The dielectric is often a matrix PE, PU, PTFE, microporous PTFE, FEP…
- Shield ❸-❹: one or more conductive braids surrounding the dielectric to shield the cable. The objective is to reduce the electromagnetic interactions between the ambient environment and the cable, thus making it possible to transmit the signal with the least possible disturbance (principle of the Faraday cage)
- Protective sheath ❺-❻-❼: the sheath protects the cable from the outside environment. This sheath adapts to external environmental constraints (temperature, humidity, protection against a fluid, UV resistance, etc.) and to the conditions of use (crushing, mechanical constraints, etc.). The cable can have several layers of protective sheath: metal sheath ❻, elastomer sheath ❺, thermal protection sheath ❼,

At Atem, we distribute RF & microwave coax cables in the following categories:

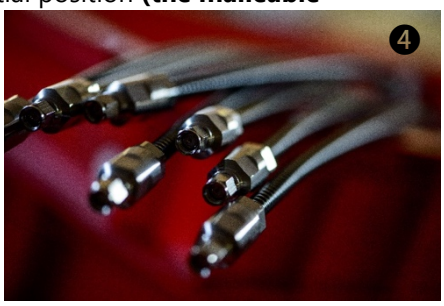
- Flexible coax cables: flexible cables ❶ to be distinguished between "standard" and "technical". The so-called "standard" flexible cables have RF performance defined according to different standards (RG, KX, etc.). The so-called "technical" flexible cables have optimized RF performance according to the manufacturer's process: in particular very low losses and phase stability (temperature and bending). They are often used for specific applications (defense, aeronautical, etc).



- Semi-rigid coax cables: semi-rigid cables ❷ are used for applications where the integration of cables is very constrained in terms of mechanical bulk. **The semi-rigid coax cable assemblies** are shaped (bending) during its manufacturing in 3 dimensions if necessary according to a plan or a CAD model. Certain technical flexible coax cable assemblies can be a good alternative to semi-rigid ones (easy integration).

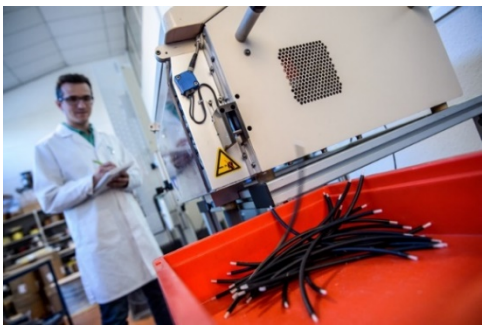


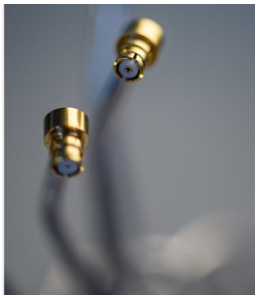
- Conformable cables: conformable coax cables are used mostly for prototyping (they present in particular a greater risk of degradation in the event of vibration stress). They are hand formable. This shaping is less stable over time compared to the semi-rigid coax cables assemblies, some ones tend to keep the shape (**the conformable**) and other ones return naturally to their initial position **(the malleable or the ultra-malleable❸)**.



- Power coax cables ❹: ability to pass pulses of the order of several kW. It is a cable that can be the **corrugated** type for example.

Before manufacturing the coax cable connection, it is necessary to strip the cables via a stripping machine, either automatic or manually. The stripping is carried out according to a specific cutting length standardized for each type of connector, allowing the placement of the connectors. We use different types of standard connectors (SMA, BNC, N, SMB, SMP, 2.9, 2.4…) depending on the frequency of use and we are also able to have them developed depending on the applications. We also use all types of female, male, elbow, straight connectors that exist on the market.





Once the coax cable is stripped and the connectors selected, assembly can be carried out. Several processes are possible and they are all mastered internally by our operators which are all IPC-620 certified:

- Crimping with crimper pliers: the most widespread process very suitable for rather low frequency bandwidths (<1GHz);

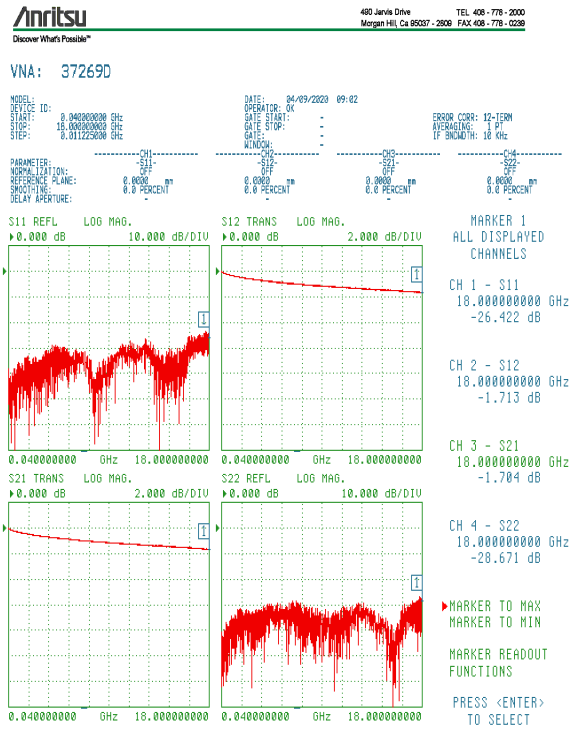
- Cable gland;
- Soldering pliers or joule effect pliers;
- **Brazing with micro-torch**: process mainly used at Atem and almost compulsory when the coax cable assemblies are technical and the desired frequencies high (more than 10 GHz). This technique provides a very directive and localized supply of heat to optimize the quantity of tin / lead material to be applied to ensure the correct soldering of the connector on the cable and not to degrade the elements of the coax cable assemblies.

Note: All our operators are IPC-620 and continuous training ensures mastery of the process (no degradation of the connector and the cable, no air bubble, process repeatability…)

IPC/WHMA-A-620

Each coax cable assembly responds to a marking plan desired by the customer. Atem can also add a serial number to ensure the traceability of the various components of the coax cable assembly: thus, **all coax cable assemblies are unique!**

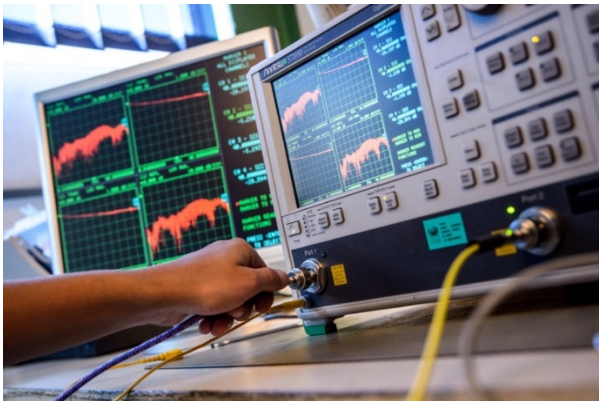
Once the coax cable assembly is manufactured, it is checked in our test and measurement laboratory. The results are traced and archived (it is possible to find the test sheets several years later). The measurement readings are the **S parameters** of the assembly. The S parameters connect the incident waves with the waves reflected by the ports of the device (in our case the 2 connectors at each end of the cable). Thus, a microwave device is completely described as it is "seen" at its ports:



- S11: reflection coefficient at the input when the output is suitable (avoid reflections)
- S12: reverse transmission coefficient when the input is suitable
- S21: direct transmission coefficient when the output is suitable
- S22: reflection coefficient at the output when the input is suitable

The S11 and S22 parameters are used to quantify the SWR (Stationary Wave Ratio). The Standing Wave Ratio or Voltage

Standing Wave Radio (VSWR) is the ratio of a maximum to an adjacent minimum of a particular component of the electromagnetic field. The closer the SWR is to 1, the better the signal transmission (little stray reflection). The S12 and S21 parameters make it possible to quantify the losses of the link. These measurements are made by VNA network analyzers. At Atem we have 3 VNA allowing us to conduct measurements up to 40GHz.
In the example, the insertion loss is 1.7dB at 18GHz for a return loss of 26dB, which amounts to a VSWR of 1.1.



Note that for specific multi-antenna and multi-channel applications, the phasing between coax cables assemblies, also called "phase matching", is a key step in the proper functioning of the system. The phasing of the signals implies an identical electrical length for each coax cable assemblies and therefore a very precise cutting capacity. In practice, this requires a resumption of the length of each cable after an intermediate RF measurement.
It is also possible to perform a matching in amplitude or in propagation time of a group of coax cable assemblies.

Once all the operations have been well described and the definitions laid down, let us focus on defining the steps in order to select the coax cable assemblies useful for your applications.

How to define and select your coax cable assemblies

See above the steps to define and select your coax cable assemblies:

1. Bandwidth selection: the frequency bandwidth is done by the operating frequency use of the RF and microwave systems. This bandwidth has a direct impact on both the connectors and the coax cable selection. Besides, the operational application, the RF performances, the number of connections, the way to operate the assemblies, the phase matching requirements are key parameters to determine your coax cable assemblies;

2. Length selection: what are the different elements of the systems which require to be linked thanks to coax cable assemblies? What are the geometrical separation between all the elements of the RF and microwave system? The length of the coax cable has a direct impact of the insertion loss. Atem has a tailor-made approach and can easily adapt the rightful length. For integrations with semi-rigid coax cables, 3D analyses are mandatory to determine the way of shipping of all the semi-rigid coax cable assemblies. With both the bandwidth and the length, the Atem design office can assess the required insertion loss and so the coax cable's type (standard flexible coax cable, technical flexible coax cable, semi-rigid coax cable…)

3. Connectors selection: Atem propose its own references, standard references and other manufacturer references. The company is able to make specific connector development on demand. The Atem design office has to check the compatibility between the bandwidth, the coax cable and the connectors;

4. RF & microwave performances: the performances of the coax cable assemblies are directly linked to the performances of the RF system. The RF system designer through the development will define the insertion loss, the power signal, the phase stability requirements…;

    a. The transmission of power through the coax cable will be mandatory such as ground radars, the insertion loss shall be the weakest as possible such as air board connectivity systems (to enhance the data flew rate available for passengers), the system requires phase stability for signal treatment or multichannel systems…
    b. The Atem design office has the skills to translate RF system requirements at top level to specific requirements at interconnection level and thus design and manufacture the coax cable assemblies within the RF and microwave system

5. Geometrical separation requirements: mechanical constraints have to take into account in terms of both bend radius (which determine the type of coax cable between semi-rigid and flexible coax cable, over reaching the bend radius would make the cable irreparably) and diameter of coax cable (higher the diameter is weaker are the insertion less).

6. Environmental constraint requirements: the environmental and operational conditions have to be defined to select correctly the protective sheaths and determine the rightful coax cables and connectors which will be compliant with these constraints.

Finally, another issue is relative to the quality management requirements. Indeed, specific sectors focused on security such as aerospace, health and nuclear sectors require an accreditation policy for the company (EN 9100 for aeronautics for example). These requirements enforce the traceability of the products and all the documentation linked to the manufacturing processes of the company. Furthermore, coax cable assemblies need the availability of both coax cables and connectors and so a performant supply chain management to offer attractive lead times. Atem is certified EN 9100.

The Atem's tailor-made approach allows our customers to get the best coax cable and connectors selection answering all the constraints described see above at the best price. Atem has been a manufacturer of customized coax cable assemblies for 30 years and has developped a worlwide supply chain to propose the competitive interconnection solutions. The failure often occurred precisely at the interconnection level and providing our customers with the good solutions is our DNA.

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