

Making a Case for a New Connector

—Research on an Optimal Design for QMA and QN Connectors

© IEEE, Feature Article in Microwave Magazine February, 2008 Volume: 9 Issue:1

The emergence of Quick Lock connectors, particularly Quick Lock versions of the SMA and N connectors (QMA and QN respectively), was an inevitable development in the RF Connector Industry, and is of significant importance in that nearly 50% of all practical applications for RF connectors are currently supported by either SMA or N. Once QMA and QN can achieve similarity in cost and performance to the present SMA and N connectors, they will take the place of their predecessors in most applications, creating a huge new market. Our RF team has long been dedicated to research and development of these two connector types, in the hopes of creating an optimal design. In this article, we will show some of the results of our research.

● Origin of the Quick Lock Connector

In looking at the limitations of connectors with threaded connections, such as SMA and N, the need for the development of Quick Lock Connectors becomes immediately clear. The SMA and N connectors are two of the earliest invented, as well as widely used, connectors in the RF coaxial connector family. SMA is used for low-power transmission, with an operating frequency of DC-18GHz $VSWR \leq 1.3$, while the N type connector is applied in medium-power transmissions, having an operating frequency of DC-11 GHz $VSWR \leq 1.25$. There is also the precision type N connector with an operating frequency of DC-18GHz $VSWR \leq 1.08$, and another precision type connector based on the N type design, APC-7, which has an operating frequency of DC-18GHz $VSRW \leq 1.003 + 0.002(f)\text{GHz}$ (See Figure 1).

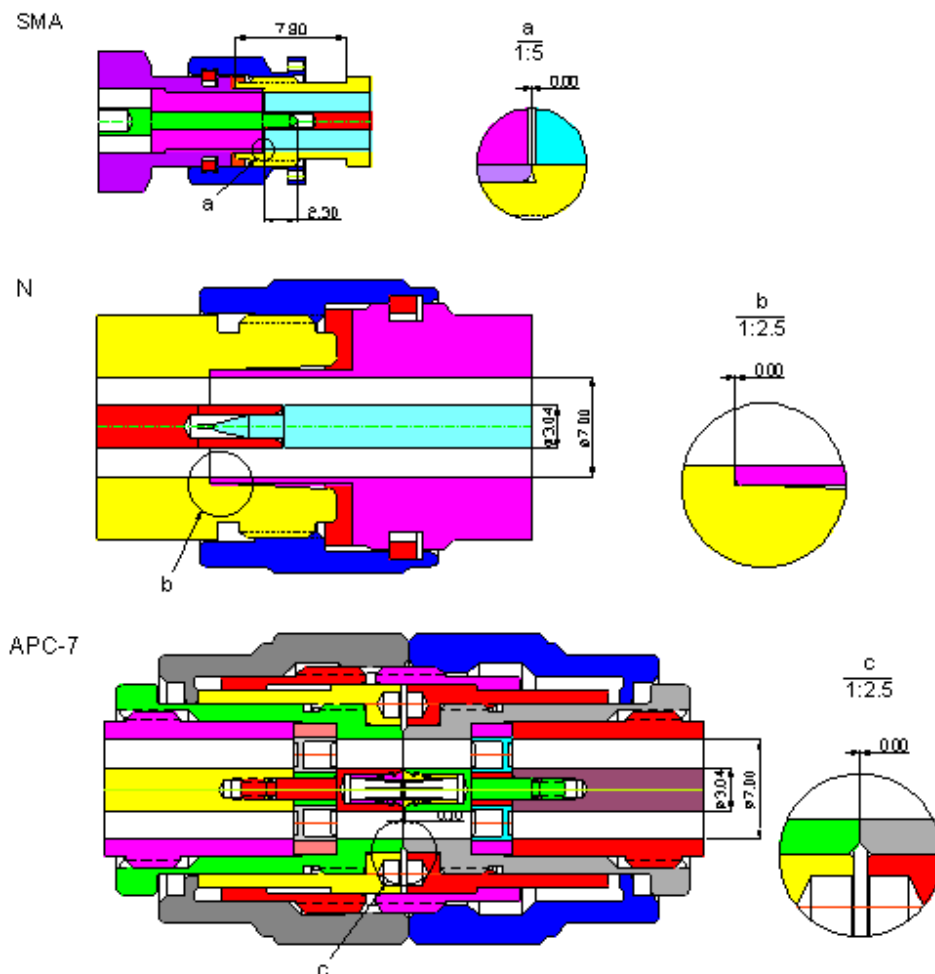


Figure 1

Despite controlling 50% of the RF connector market at present, the rapid development in the electronics industry has created a demand for higher standards by users ranging from communications equipment manufacturers (e.g.: Motorola, Nokia, Ericsson) to the military. They are eager for connectors that meet the following requirements:

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- Provide a reliable connection while at the same time allowing for fast mating and de-mating so as to increase work efficiency
- Develop a small size, light weight, high density design that takes full advantage of available space
- Eliminate the need for specialized tools
- Allow for 360° rotation in the mated position without impairing performance
- Reduce the need for operational training by making operation simple and reliable
- Lower cost

The threaded connection of traditional SMA and N connectors can hardly meet all these requirements, in a market that is badly in need of connectors which can. As a result, the research for Quick Lock connectors began.

● Resolutions and Analysis

RF connector manufacturers Huber +Suhner and Radiall were the first to begin research and development on the Quick Lock design. In the past few years, they have successively released QMA (patent No.: U.S. 6,692,286) and QN (patent No.: U.S. 6,709,289), and together with Amphenol RF and Rosenberger established the QLF alliance so as to share technology, unify interface standards, and profit from joint marketing (see www.qlf.info) . Presently, QLF's versions of QMA and QN are the most widely used on the market. In the following analysis and comparison of these QLF connector designs, it is shown how new design ideas were reached.

QMA:

Below is the design for QLF's version of QMA (Figure 2).

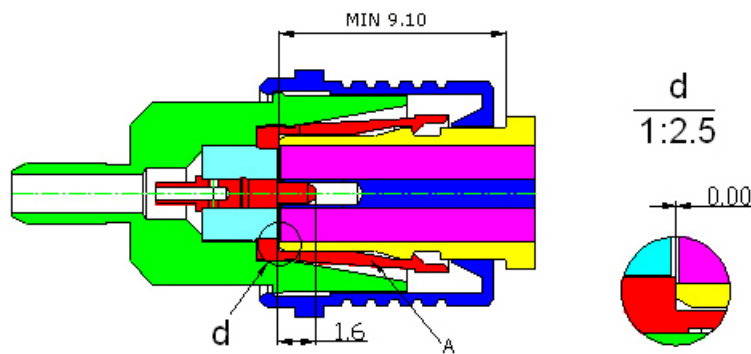


Figure 2 QLF's QMA

Testing shows this design to be fundamentally sound, as it can approach SMA's relatively high electrical performance. However, small problems still exist.

- The QMA connectors currently available on the market have no waterproof seal, allowing water and gas to penetrate the connector thereby reducing the reliability of its contact conductors. QLF has recently claimed to have released the world's first waterproof QMA, which is also said to be backwards compatible with the present QMA female (A Waterproof QMA Coaxial Connector, *Microwave Journal: Cables and Connectors Supplement*, March, 2007). This would effectively resolve the current problem, though we haven't been able to find or test this new product.
- The spring-lock in the QMA connector's design requires the use of beryllium copper. This mineral is in itself expensive, add to which the difficulty there is in processing it and its need for thermal as well as environmental protection treatment and the overall cost becomes very high.
- When the QMA male and female are mated, the effective contact length of the inner conductor is too short, being only 1.6 mm, whereas the effective contact length of the original SMA is 2.3 mm (see figure 1). After several uses, this may result in the reduced contact reliability of the inner conductor.

These three areas are the main respects in which QLF's version of QMA can be improved upon, and in fact have been in a new version of QMA (hereafter referred to as QMA, See figure 3) which is soon to be released and successfully resolves all these problems.

- QMA's waterproof seal is cleverly designed so that when under pressure from an upslope on the surface of the female outer conductor (see figure 3, 1), an O-ring that rests in a groove of the male outer conductor creates an excellent seal and anti-shock effect.

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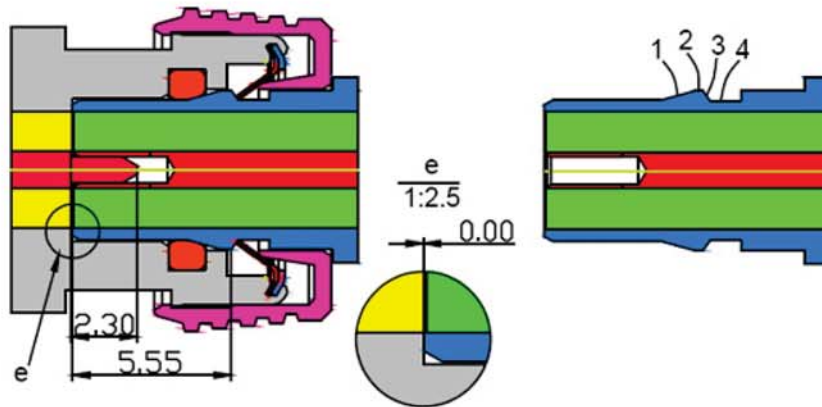


Figure 3 QMA and QMA Female Outer Conductor

- In the QMA design, the stainless steel spring-lock in the plug, which costs only 1/10 that of the beryllium copper spring-lock in the QLF's QMA, consists of a ring-like locking sheet with inner (see figure 4, 1) and outer teeth (see figure 4, 2). A cross section of the QMA female shows that on the surface of the outer conductor there is an upslope (see figure 3, 1), flat top (see figure 3, 2), down slope (see figure 3, 3) and then a flat valley (see figure 3, 4). Thus, when connecting, the inner teeth reach their maximum flexural deformation while rising along the upslope, then while moving along the flat top the deformed inner teeth are gradually restored to their original state in the tangential direction of the down slope before finally stopping at the down slope, or at the juncture of the down slope and the flat valley (see figure 5). The ends of the inner teeth, by thrusting into the down slope, force close contact between the surfaces of the outer conductors, with zero clearance and a relatively strong contact force: **a high contact force results in good passive intermodulation (PIM) performance.**

Furthermore, the adjacent inner teeth of the ring-like locking sheet have different lengths, which enable them to stop on different circumferences of the down slope when locking. The angle between the longer teeth and the down slope is $\geq 90^\circ$ (see figure 5, a & b), while that between the shorter teeth and the down slope is $\leq 90^\circ$ (see figure 5, b & c). This design creates excellent retention force and anti-shock performance. In addition, the effective mating cycles of QMA is over 200 times.

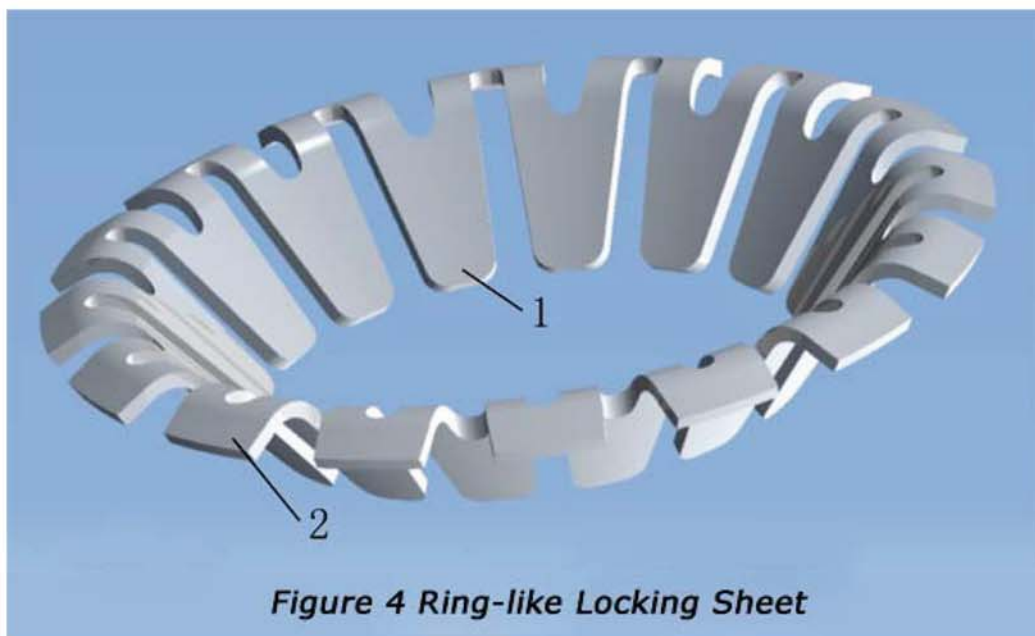


Figure 4 Ring-like Locking Sheet

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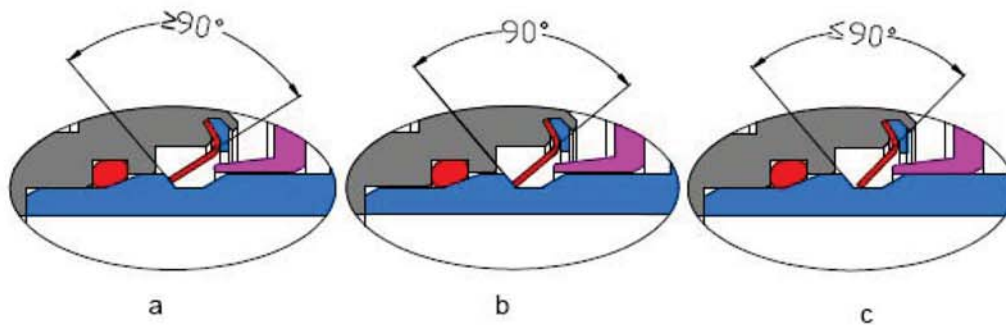


Figure 5 Degree of Contact for inner teeth

- In the interest of improved reliability, the effective contact length of the original SMA conductor, 2.3mm, ought to be maintained, and is matched in the QMA design.

Two further notes:

- The QMA plug is completely backward compatible with the QLF's QMA jack.
- In addition, for the purpose of saving space and material, a mini-version of QMA (hereafter referred to as Mini-QMA, see figure 6) has been designed; which combines comparable performance with reduced volume.

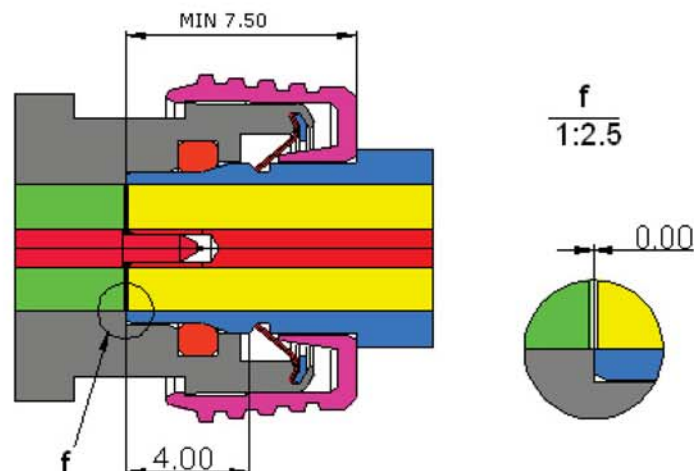


Figure 6 Mini-QMA

QN:

As a matter of fact, as early the 1980s, Chinese RF engineers had already developed a Quick Lock Connector based on the N connector's design (See Figure 7). This connector performed well, especially when applied in special circumstances.

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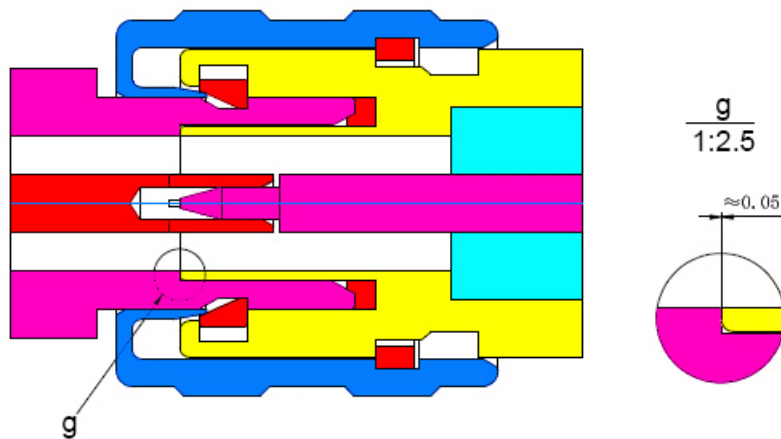


Figure 7 80's Quick-lock N design from China

The following are three versions of QN that were released successively by QLF founder Huber+Suhner beginning in 2002.

1) 2002 version (See Figure 8).

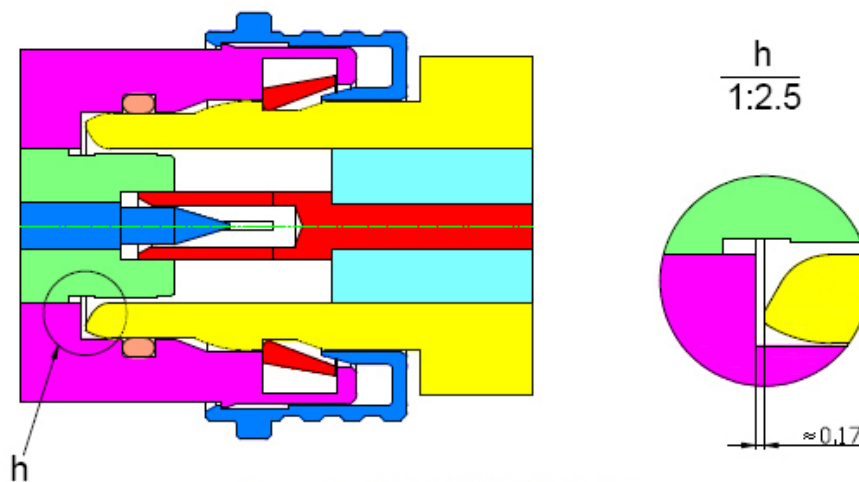


Figure 8 QLF's QN (2002)

QLF's 2002 version was the first to successfully convert the N type connector's original threaded connection to a snap-fastening, self-locking one.

Advantages:

- Improved mating and de-mating efficiency as a result of a snap lock mechanism that requires no tools.
- The dimensions of the conductor were decreased, reducing its weight between 20-40%, in addition to requiring 20-50% less copper to manufacture.
- The increased installation density of the connector saves installation space.
- In the mated position the connector allows for 360° rotation.
- Requires little or no training to mate and de-mate the connector.

Disadvantages:

- Extra parts require a high degree of processing accuracy because the clearance between electrical contact surfaces is completely controlled by the processing accuracy.
- If there is clearance between the contact surfaces there will be no contact force which will affect the standing wave and passive intermodulation.
- By not adopting the basic parameters of the N type connector, QN had to be completely re-designed, re-inspected and verified resulting in a great deal of work.

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2) 2003 version (See Figure 9)

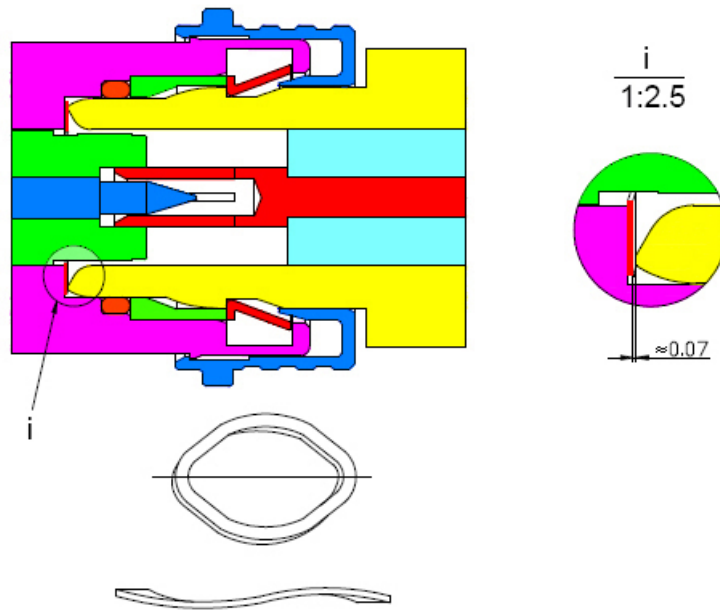


Figure 9 QLF's QN (2003) with Wave Spring Washer

The 2003 version of QN made improvements based on the 2002 design

Advantages:

- A wave spring washer was added to the contact interface of the connector in order to increase the axial pressure and eliminate the clearance between contact surfaces with its elasticity.
- Reduced contact resistance, which helped to improve the passive intermodulation.

Disadvantages:

- By placing a wave spring washer on the contact surface of the connector the problem of clearance was solved, but there is contact at only a few points on the circle's surface and the impedances around them are not well matched. This in turn can cause reflection of the electromagnetic wave at these points. As a result, this connector works well in DC-1.5 GHz and can also work in 1.5-3.0 GHz. However, if it is used in 3-6 GHz, the standing wave will be high, and will be still higher in 6-11 GHz.

3) 2004 version (see Figure 10).

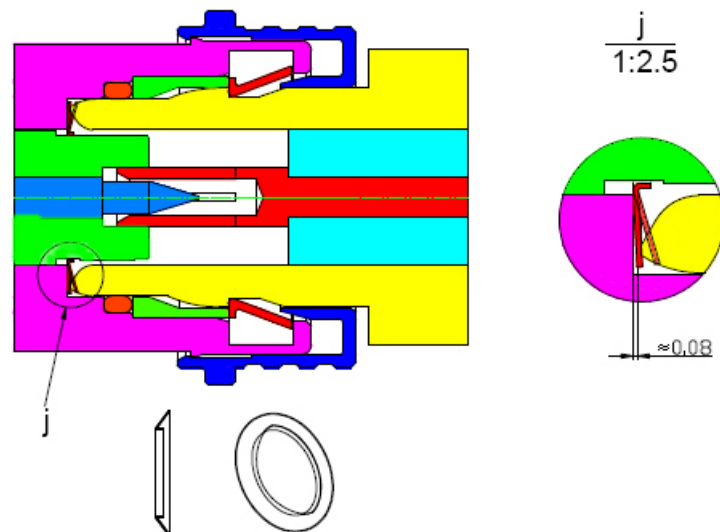


Figure 10 QLF's QN (2004) with Radial Disk Spring

In the 2004 version, further improvements were made based on the 2003 design.

Advantages:

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- The wave spring washer on the contact surface of the connector was replaced by a radial disk spring, which increases axial pressure while reducing contact resistance and improving contact stability.
- By using a radial disk spring, the contact between the spring and the contact surface is not just at a few points but a whole circle. This further improves the PIM while reducing the standing wave and insertion loss.

Disadvantages:

- Since the contact surface of the outer conductor is tapered to a point, a relatively high axial pressure is generated under the influence of the radial disk spring, improving contact resistance. However, as the space formed by the sharp end of the outer conductor and the spring is an irregular shape, by using the transmission theory,

$$Z_0 = \frac{60}{\sqrt{\epsilon}} \ln \frac{D}{d}$$

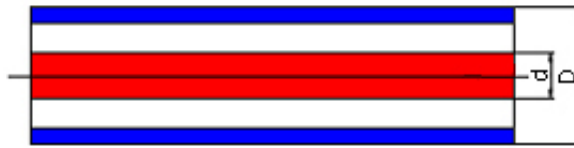


Figure 11 Transmission Theory

Z₀: characteristic impedance of ideal coaxial line; **D:** inner diameter of the outer conductor;
d: outer diameter of the inner conductor; **ε:** dielectric constant .

it is shown that the characteristic impedance in this part is not continuous and may cause a rather large reflection, especially when transmitting high-frequency electromagnetic waves. The standing wave is quite good in DC-1.5GHz and acceptable in the 1.5-3GHz range. However, it may cause trouble when used at 3-6GHz, and still more at 6-11GHz.




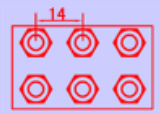
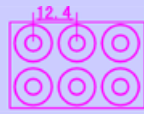
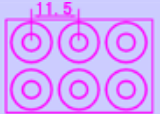
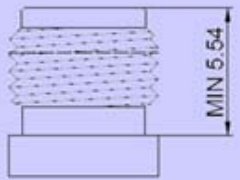
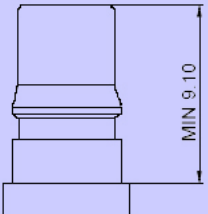
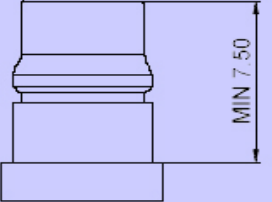

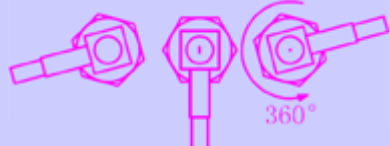
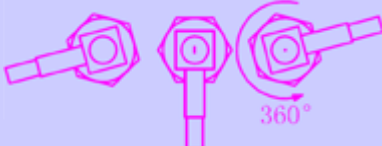



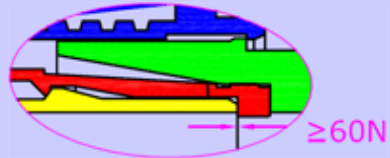
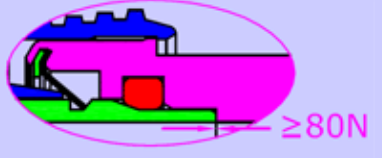
- This version still does not make use of the basic parameters of the original N type conductor, i.e. the external diameter of the inner conductor, 3.04 mm, and the internal diameter of the outer conductor, 7.00 mm. As a result, a great deal of time and energy went into the redesigning, retesting, and verification of this product, and all the valuable experience accumulated over tens of years of testing and working with the N type conductor have been wasted. This goes against the basic principles of Industrial Design.

In this newest version of the QN conductor, further improvements can still be made in the following areas:

- The three classic RF coaxial conductors, SMA, N, and APC-7, are all able to achieve high bandwidth and low VSWR primarily as a result of the zero clearance in contact interface, which allows for continuous impedance and almost no reflection between their contact surfaces. However, the QLF's QN conductor design's use of a spring contact will in all likelihood result in discontinuous impedance. The Quick Lock N type connector should base its structure on the rigid contact design of the original N type conductor, which guarantees continuous impedance between contact surfaces and enables it to maintain the N type's electrical performance: DC-11GHz VSWR<1.25, with the precision type N able to reach DC-18GHz VSWR<1.08. The newly designed HPQN adheres to these principles by adopting a spring lock made of stainless steel similar to that used in the QMA, which allows for rigid contact between the contact surfaces and ensures continuous impedance. That is to say HPQN maintains the performance indexes of the original N type conductor, while requiring only 80% of the material necessary to manufacture the QLF's QN design.

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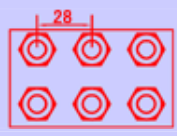
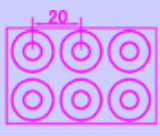
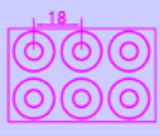



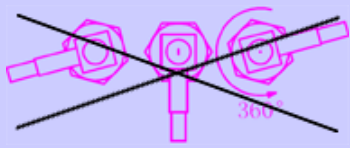





Data sheet for SMA, QMA, Mini-QMA

ITEM	SMA	QLF'S QMA	Mini-QMA
Coupling Mechanism	1/4-36 UNS threaded connection	snap-fastening (beryllium copper)	ring-like locking sheet with inner and outer teeth (stainless steel)
VSWR	DC-18GHz, VSWR \leq 1.3	DC to 6 GHz Optimized DC to 18 GHz Working range DC to 3 GHz, Return loss \geq 32 dB 3 to 6 GHz, Return loss \geq 25 dB	DC-18 GHz, VSWR \leq 1.3
Mating/De-mating Time (seconds)			
Installation Density (millimeters)			
Length of Female Connector			
360° Rotation after Mating			
Torque Wrench Requirements for Installation			
Waterproof Sealing	IP68	pending	IP68
Connection Reliability	the threaded connection may become loose due to vibration	the clasp will not loose, but the elastic strip may become loose.	the locking sheet will not loose.
Cost of Spring Mechanism	N/A	10x	1
Necessary Installation Training	specialized training	simple training	simple training
Durability	mating cycles= 500	mating cycles= 100	mating cycles> 200
Interface Retention Force	—		
Effective Contact Length of Inner Conductor	2.3 mm	1.6 mm	2.3 mm

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Comparison Results: In comparing the Quick Lock QMA with QMA it can be seen that both could take the place of the traditional SMA connector. However, QMA is superior to QMA in mating pitch, sealing, material cost, retention force and mechanical lifespan, while it is inferior to QMA in none of the indexes. Therefore, it is a better choice than QMA to replace the original SMA.

Data Sheet for N, QN, HPQN

ITEM	N	QLF's QN	HPQN
Coupling Mechanism	5/8-24UNEF threaded connection	clasps in the slits of connector	ring-like locking sheet with inner and outer teeth (stainless steel)
VSWR	DC-11 GHz, VSWR≤1.25	DC to 6 GHz Optimized DC to 11 GHz Working range DC to 3 GHz, Return loss≥32dB 3 to 6 GHz, Return loss≥25dB	DC-11 GHz, VSWR≤1.25
Mating/De-mating time (seconds)			
Installation Density (millimeters)			
Torque Wrench Requirements for Installation			
360° Rotation after Mating			
Reliability	the thread may become loose due to vibration	the clasp may loose slightly	the locking sheet will not loose.
Clearance between Contact Surfaces	rigid zero clearance	solved the problem of clearance with an elastic component.	rigid zero clearance
Impedance	50 Ω continuous impedance without reflection	discontinuous impedance with reflection	50 Ω continuous impedance without reflection
Necessary Installation Training	specialized training	simple training	simple training
Materials	 100%	 50%-70%	 30%-50%
Durability	mating cycles=500	mating cycles=100	mating cycles>200

Comparison Results:

In comparing QN with HPQN we can see that:

- By adding an elastic component, QN solves the problem of clearance between contact surfaces but at the same time causes the

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impedance between the contact surfaces to be discontinuous. Therefore, the transmission of high- frequency electromagnetic waves will cause reflection and poor electrical performance, especially at 6-11GHz. As for HPQN, it maintains the rigid contact, zero clearance and axial pressure of the original N-type conductor. Impedance also is continuous on the contact surfaces with very little reflection and low contact resistance resulting in the quality electrical performance of the N type: DC-11GHz VSWR<1.25.

- The material necessary for producing the HPQN is 30%-50% that of the N type connector, which directly reduces the cost of processing equipment, measuring tools, electroplating, packing and transportation.
- HPQN is inferior to QN in none of the indexes.

The above results show clearly that HPQN is a better choice than QN to replace the traditional N connector.