06/14

Low PIM

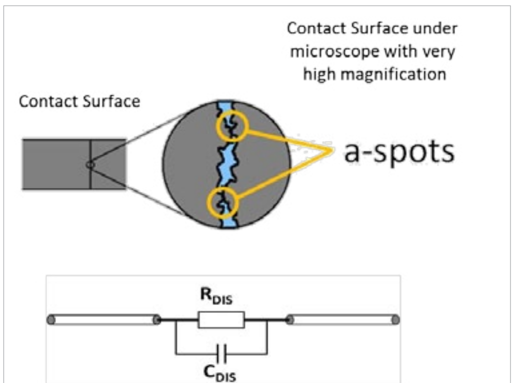
ConductRF Advice & Support

PIM: Components, Material, Handling & Testing

by Wolfgang Damm | AWT Global

New connector surfaces look and feel very smooth, but the picture changes quickly when viewed under a microscope. The atomic lattice size of metals is often no more than 25 Angstroms (0.0000025 mm) wide. Machined metal surfaces will never have such a degree of smoothness. Metallic surfaces look indeed very rough under high magnification. That causes surfaces of mated connectors to touch only at a few spots, called asperities. Tightening connectors applies localized pressure to these asperities, which causes them to deform. Deformations increases the contact area, but it is still limited to some load-bearing areas, so called a-spots. They add up, but their overall area is still by several orders of magnitude smaller than the apparent contact surface of connectors.

Simplified, a-spots can be regarded as electrical RC models and a mated connector can be seen as network of thousands of unequal RC circuits. Such a network does not behave in a linear way. Passing currents of different frequencies will respond differently, causing passive intermodulation.



RC – Model of an a-spot

Structural material discontinuity causes also discontinuity in current flow. Regardless of the contact material, discontinuity in electron flow is characterized by:

- Constriction Resistance due to bending of current lines of flow in the vicinity of an a-spot.
- Tunnel Resistance due to conduction through thin insulating contaminant layers via tunnel effect.
- Contact Capacitance between the two essentially parallel equipotential surfaces.

Lengths of the constrictions are very short, so inductive effects are small compared to capacitive and resistive effects.

Skin Effect

Skin effect is called the property of alternating current to show higher current density closer to a conductor surface. Current flows mainly at the skin of the conductor between the outer surface and a level called the skin depth. Skin effect is caused by eddy currents that are induced by the changing

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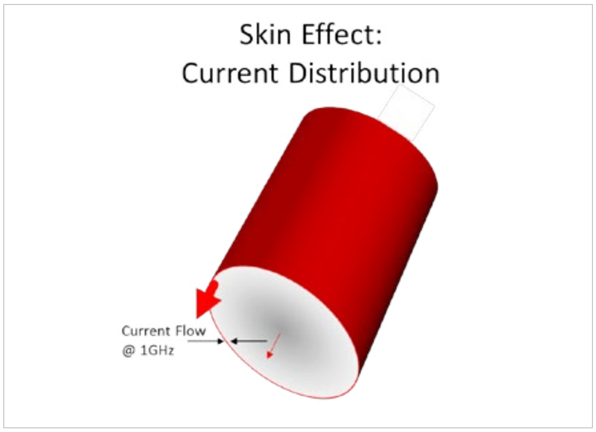


magnetic field of alternating current. The effect is more pronounced with higher frequencies. At 1 GHz, on a silver plated surface, around 98% of the current density occurs within approximately 0.01 mm of material depth. For comparison: an average human hair has a diameter of 0.08 mm, 8 times larger in diameter than the skin depth at 1 GHz. This fact underlines the importance of connector plating. It serves not only as protection for the connector but carries almost all of the current in RF systems.

The remarkably diminutive skin depth of conductors at high frequencies is very susceptible to scratches in the material. Even if only on a microscopic scale, the tiniest groove, dent or jag interferes with homogeneous flow of current and with that, causes unwanted passive intermodulation.

Working With Low PIM Components

Whether connectors, cables or components, low PIM components are precision building blocks of RF networks. Low PIM products require manufacturing processes that meet highest standards, 100% quality sampling, carefully handling and shipping with sufficient protection. These components have to be treated carefully also in the field to avoid degrading or damage. Since components like duplexers or loads are often hermetically sealed, their internal elements are relative protected, but their connectors are exposed. This is also the case for cables. This chapter is about treating connectors of cables and component ports.

Mechanical Damage

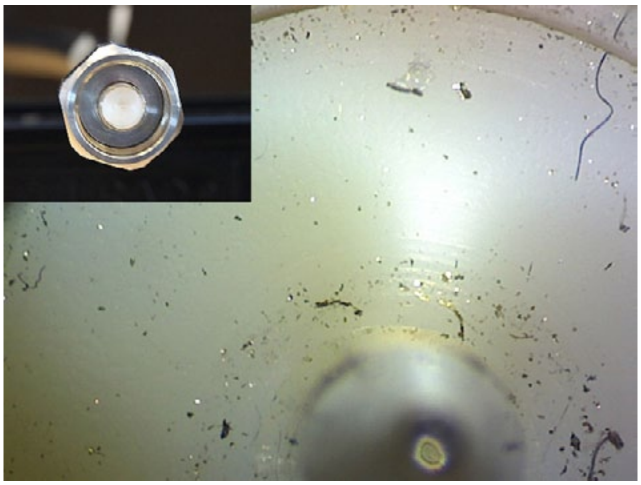
Mechanical damage can be inflicted by a variety of events. Dropping a component is the most obvious mishap, but it can occur already in the factory and during shipment if loose components are allowed to bump into each other. A less obvious cause is improper connector tightening. RF connectors are designed in a way that they can be screwed on almost completely by hand. Wrenches are to be used only for the last half turn. It clearly indicates non-parallel mating of connectors if it is too tough to screw them on by hand. This can be caused by too short or too long cables, which apply sideways pulling or pushing forces to connectors. If RF connectors do not turn easily during mating, their threads and connecting parts are forced against their counterpart surfaces, causing extreme friction and even deforming. High forces can chip of parts of the plating. These conducting chips are alien bodies that interfere with the current flow in the RF path, causing passive intermodulation distortions. Cables' geometry is paramount for proper functioning. It can be damaged by external force (denting) or too tight bending radii. A good practice is to install release cable loops to avoid both, forces at the connectors and too tight cable bents. Such loops cost a bit more material, but the investment goes a long way as the installation tends to be more reliable over time. After connectors are pre-tightened by hand, they have to be mated with a torque wrench to apply exactly the right tightening force. Connections with too little torque result in insufficient contact force, too much torque causes contact areas to deform. Both are consecutively resulting in passive intermodulation distortion.

Working with low PIM components

- Prevent mechanical damage
- No touching of RF conductors with bare fingers
- Avoid alien bodies of all kind
- Avoid humidity
- Avoid electrical damage

Alien Bodies

Alien bodies like dust, dirt, metal chips can very easily find their way into connectors. Base station sites or in-building installations are never dust free, and dust and dirt kernels are difficult to avoid. Keeping protection caps on connectors helps. It is suggested to wipe connectors always with alcohol wipes and dry them with moist free canned air before mating. While connector dust might not be visible to the bare eye, dark areas of used wipes will clearly show that it has been there. Connectors of test equipment, measurement cables and low PIM terminations have to be cleaned frequently with alcohol wipes and dried with moist free air.



The N-Connector in the small image top left looks clean with bare eyes. The view though a microscope reveals however many alien bodies that can be a serious source of passive intermodulation distortion.

Humidity

Humidity and moisture are creeping enemies of low PIM networks. Over time they cause oxidation. While initial measurements may look good, connectors with accidentally enclosed humidity and moisture will degrade. An often overseen but common source of humidity is human breath. It is tempting to blow into a connector to remove a little dust fluff. Never do it. Exhaled air has a relative humidity of 100%!

No Touching of RF conductors

Sweat cools the body and skin lubricates itself with oily matter. What is helpful to maintain our health is adverse to proper function of RF connectors. Even minuscule amounts can alter PIM performance of connector contact areas. Low PIM RF conductors are very susceptible to such external influences. There is a good reason why manufacturers of low PIM components require their workers to wear gloves.

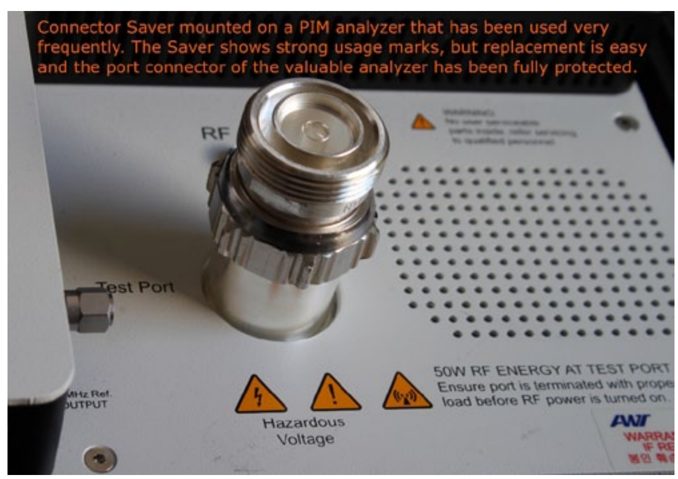
Electrical Damage

Electrical damage is easily overseen but often cause of serious PIM problems. It can happen by applying power levels to a device that exceed its actual power rating. Without question, that has to be avoided. Another occurrence that happens sometimes unintentionally is mating and disconnecting connectors under RF power. If this happens, spark discharges are unavoidable. They cause craters in the material, altering current flow significantly, which is a source of PIM.

Connector Wear

Connector wear is an issues that concerns test equipment including PIM analyzers, test cables and low PIM terminations. It is no so much an issue for field installations because connectors of low pim components are mated only a few times, for initial system measurements and final mating. Test equipment at the other hand, is in permanent use and has to endure many mating cycles.

Manufacturers guarantee typically 500 mating cycles with sustainable PIM ratings before connectors start to degrade. The reason is clearly not low quality but the fact that asperities can undergo only a limited number of deformation cycles. Furthermore, attrition of conductors' plating due to mechanical friction reduces the thickness of the plating steadily.



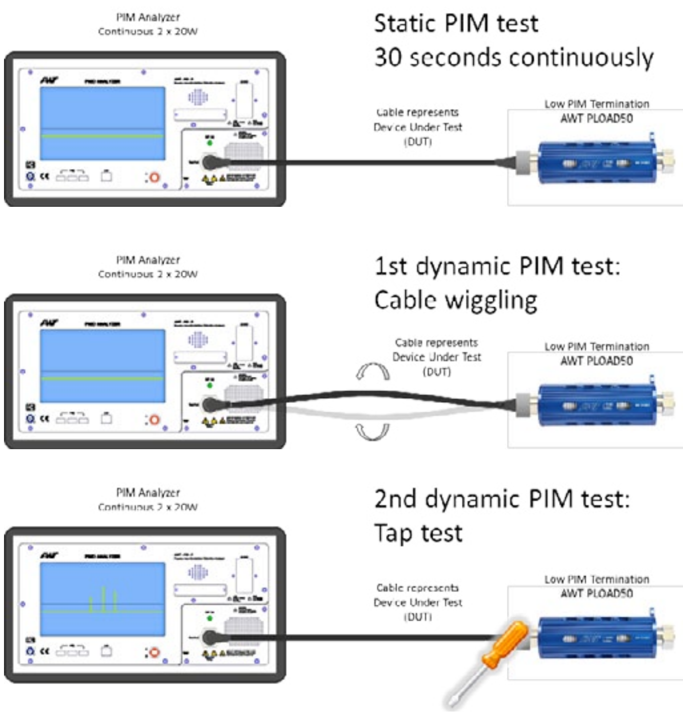
Connector Saver mounted on a PIM analyzer that has been used very frequently. The Saver shows strong usage marks, but replacement is easy and the port connector of the valuable analyzer has been fully protected.

Testing Low PIM Components & Networks

Low PIM components are a key factor when building telecommunication networks with lowest passive inter-modulation interferences. However, 60% of all PIM issues are not caused by faulty components but are man made and happen during installation. This particularly because RF-cables are usually assembled in the field.

Unintended scratches in the plating, chipping, entrapped dust are just a few of many issues that can occur. The only way to ensure that base station installations operate at the expected low pim levels is to conduct thorough PIM tests of both, individual RF branches and the complete installation. Three simple PIM tests have gained general acceptance and serve as excellent reference for both, installation and component testing. The tests are described below. They will detect virtually all sources of PIM in cables, connectors and components.

The static test analyzes both, components and cables. PIM analyzers that deliver continuous 2 x 20W measurement signals are connected to the Device Under Test (DUT). PIM measurements are performed for at least 30 seconds, ensuring to fully energize the system and also apply thermal stress to the tested components, similar to a live telecommunications signal. This test detects bad materials, scratched surfaces and alien bodies like dust or metal chips in the RF path.



Measurement values of static tests need to be below the required limit, but they should also be stable. The signal should not alter too much during the measurement. Changes of 2-4 dB are acceptable, higher swings - even if they are within the required limits - can be an indicator for (future) PIM problems.

The first dynamic test, also called wiggle test, checks the quality of assemblies between cables and connectors. Tested cables are moved in a circular way (turn diameter about 10 cm). The test is to be conducted with at least 10 turns in each direction. Wiggle tests detect loose contacts and poor workmanship of cable assemblies. They find also bad soldering and shielding cracks. PIM measurements must be stable throughout the test. Correct cable-connector assemblies will endure this mechanical stress test easily.

The second dynamic test, is also known as tap test. It requires PIM analyzers to be set to PIM versus time mode. PIM readings are continuously shown over a time axis in this mode. A harder device, made of wood or plastic material but not metal, is used to tap 10 times at all connectors. Field technicians use often the handle of a screw driver for this test. It is hard but does not dent or scratch the connectors. PIM readings should stay stable during this test. Possible contaminations like dust, metal chips or other alien bodies in the connectors will cause spikes in the reading whenever the connectors are tapped. Remedy is to open the connectors again, clean them with alcohol wipes and dry them with moisture free pressured air. Afterwards the tap test has to be repeated.

ConductRF has developed significant expertise in building Low PIM products for many applications including Intsllaed DAS systems. Less well known is our support of the PIM test Cable Market, where we build performance Low PIM cables for providers of PIM test equipment. Though these cables are not generally available from us directly, the expertise we employ in building them is applied to every other PIM connector and Cable assembly we supply. We Know.... Results Count!

Low PIM, Plenum DAS RF Cables

SPP-250-LLPL - PLA44 Series

SMA, N, 7/16 & Mini-Din Solutions

Low Passive Intermod under -155dBc
Stable Performance when Flexed
Suitable for Indoor & Outdoor use
R/A Configurations Available
Optimized Performance to 6GHz
UL910 Plenum Rated Cable

Characteristic	2GHz	6GHz
Impedance	50 Ohm	
Cable Diameter	0.280”	
Max Voltage	750 VMRS min.	
Velocity of Prop.	76%	
Capcitance	26.7 pf/ft	
Shielding Eff.	>100dB	
Minimum Bend	1.5 in.	
Temp Range	-55C to +105C	
VSWR	Better than 1.25:1	Better than 1.35:1
Insertion Loss	Under 0.225dB/ft	Under 0.407dB/ft
Max Power	460W	250W
Connector Finish	Low PIM Silver & Tri-Metal Finishes	
Cable Jacket	FEP (Fluoroplastic)	
Environment Use	Indoor/Outdoor	

Images for illustration only, Data subject to change.

ConductRF’s PLA44 series of Low PIM flexible RF Jumper Cables provide Cellular and In-Building Wireless system designers with a versatile solution for network and cabinet cabling. The Plenum rated SPP-250-LLPL cable is suitable for Indoor and Outdoor use. ConductRF’s Low PIM RF Connectors ensure performance better than -155dBc (2x43dBm Carriers). Interface gaskets provide IP67 rated interfaces when mated providing users with confidence in extreme weather conditions. Connector choices include SMA, Type-N, Din 7/16, Mini-Din 4.1/9.5 and now 4.3/10.

All PLA cables are 100% tested for PIM in 700MHz Cellular range where PIM conditions are most prevalent. Each cable is also tested for VSWR and IL. ConductRF’s PLA44 is a proven stable solution for long term Low PIM excellence in todays DAS and LTE infrastructure build outs. ConductRF’s PLA44 series of products use materials and finishes that ensure excellent long term performance and operation electrically and mechanically for both indoor and outdoor applications. PLA44 Vex files for DAS designed can be fond on iBwave.com.

PLA44-N1NF-W03

PLXXX-YZYZ-WYY

XXX
A44 = SPP-250-LLPL

Y
S = SMA
N = Type-N
D = 7/16
4 = 4.1/9.5
3 = 4.3/10
Q = QMA

Z
1 = Straight Male
2 = R/A Male
3 = Bulkhead Mount
4 = Panel Mount
F = Straight Female

WYY = Length in Feet (W03 = 3ft)
WMY = Length in M (WM2 = 2M)

Low PIM 50Ω RF Cables

Hand Formable - FMP Series

for ConductRF Low PIM Connectors

Low Passive Intermod under -155dBc
Superior Cable Shielding
Stable Performance when Formed
Direct Solder Connector Attachment
Optimized Performance to 6GHz

Characteristic	FMP29
Center Conductor	Silver Plated Copper
Dielectric	PTFE
1st Shield	Tin Soaked Copper Braid
Cable Jacket	Blue FEP
Shielding	>95dB
Temp Range	-55C to +135C
Cable Jacket OD	0.160”
Min Bend Radius	0.400”
Max Power at 900MHz	325W
Capcitance	29 pf/ft
VSWR max	1.40:1
IL/Max Pwr-800MHz	10.1db/100ft - 380W
IL/Max Pwr-1900MHz	16.7db/100ft - 250W
IL/Max Pwr-2200MHz	18.8db/100ft - 205W
IL/Max Pwr-5800MHz	34.1db/100ft - 112W

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ConductRF FMP series Low PIM Hand Formable RF cable assemblies provides the Cellular and In-Building Wireless system designers with a versatile solution to cabling and configurations needs for optimum Antenna placement. In recognition that PIM is caused by nonlinearity of components in the RF construction, these assemblies have been designed to minimize these effects and maximize the elements that minimize PIM. Utilizing ConductRF's new Low PIM Direct Solder Attachment Connectors, we can provide high performance solutions operating up to 6GHz in configurations for Low PIM including Straight, Right Angle, Bulkhead and Panel attachment. Performance better than -155dBc is validated through 100% testing. Using FEP jacketed hand formable cable, these cables may be bent in to fixed shapes to enable specific dressing and lay of cable within a system without suffering a natural spring effect experienced with flexible cables. DAS Designers can download ConductRF Vex Files from iBwave.com

iBWAVE

FMP29-N1NF-W03

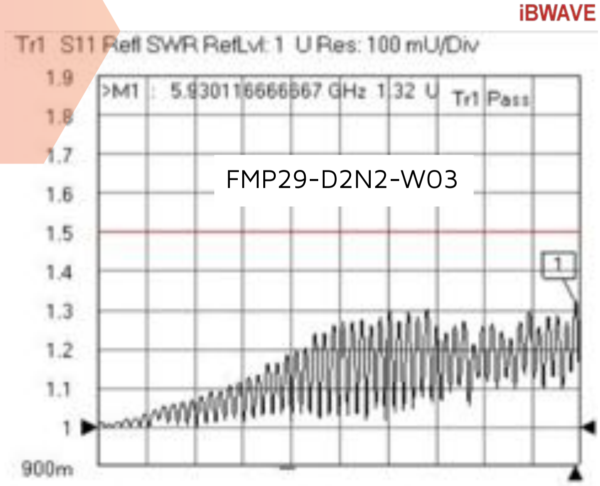
FMP29-YZYZ-WYY

YY = Length in Feet

Y
S = SMA
Q = QMA
N = Type-N
D = 7/16
4 = 4.1/9.5
3 = 4.3/10

Z
1 = Straight Male
2 = R/A Male
3 = Bulkhead Mount
4 = Panel Mount
F = Straight Female

W
W = Tri-Metal



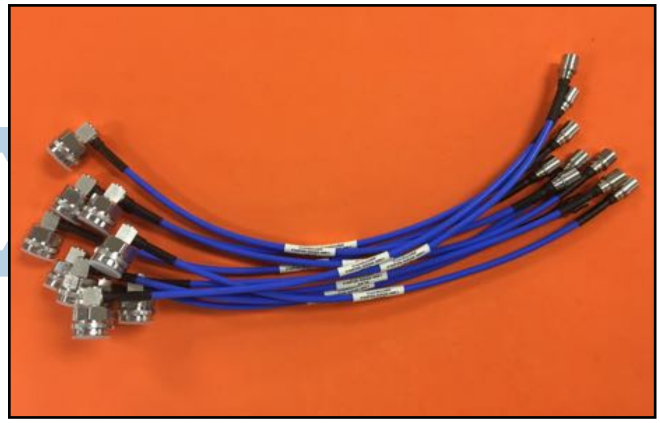
15C-FMP

Low PIM 50Ω RF Jumpers

PN Series - Flexible Double Shielded Cables

Plenum Rated Solutions for DAS

Low Passive Intermod under -155dBc
Superior Cable Shielding
Stable Performance when Flexed
Optimized Connectors Attachment
Performance Options for 3GHz & 6GHz
UL910 Plenum Rated Cable



Characteristic	PN(A/B)44	PN(A/B)29
Center Conductor	Bare Copper	
Dielectric	Taped PTFE	
1st Shield	Tin Plated Copper Flat Braid	
2nd Shield	Tin Plated Copper Round Braid	
Cable Jacket	Blue FEP	
Shielding	>80dB	
Temp Range	-55C to +105C	
Cable Jacket OD	0.265"	0.160"
Min Bend Radius	1.375"	0.750"
Max Power at 900MHz	700W	390W
Capcitance	28.2 pf/ft	26.7 pf/ft
1GHz Attn/100ft-A&B	<7.6dB	<12.6dB
2GHz Attn/100ft-A&B	<12.3dB	<20.1dB
3GHz Attn/100ft-A&B	<15.8dB	<25.2dB
6GHz Attn/100ft-B	<20.0dB	<29.0dB

Images for illustration only, Data subject to change.

ConductRF PN series Low PIM flexible RF cable assemblies provides the Cellular and In-Building Wireless system designers with a versatile solution to connecting and configuring network needs for optimum Antenna placement and overall performance. These assemblies have been designed to minimize these effects of Passive Intermodulation, PIM. Utilizing ConductRF's new Low PIM Direct Solder Attachment Connectors, we provide high performance solutions for Low PIM interconnect including Straight, Right Angle, Bulkhead and Panel attachment. Performance better than -155dBc is validated through 100% testing at our factory. Cable options are available for either DC to 3GHz or 6GHz with a VSWR better than 1.20:1 with straight connectors. New options include mini DIN variants 4.1/9.5 and 4.3/10. The cable has a durable FEP Jackets and is Plenum rated to UL910 so is ideal for In-Building DAS applications Vex files can be downloaded at iBwave.com.

iBWAVE

PNA29-N1NF-W03

PNXXX-YZYZ-WYY

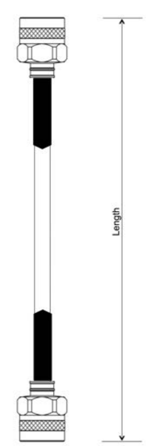
YY = Length in Feet

XXX
A44 = 0.265" with FEP Jacket DC-3GHz
A29 = 0.160" with FEP Jacket DC-3GHz
B44 = 0.265" with FEP Jacket DC-6GHz
B29 = 0.160" with FEP Jacket DC-6GHz

Y
S = SMA
Q = QMA
N = Type-N
D = 7/16
4 = 4.1/9.5
3 = 4.3/10

Z
1 = Straight Male
2 = R/A Male
3 = Bulkhead Mount
4 = Panel Mount
F = Straight Female

W
W = Tri-Metal

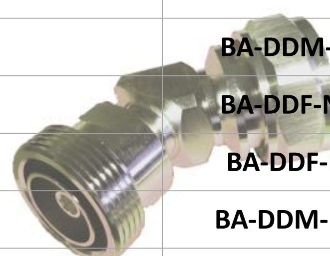


Sales@ConductRF.com - Tel: +1 978-374-6840 - www.ConductRF.com

Low PIM Adapters
In-Series and Between Series
Low PIM Series

Optimized Performance
PIM -160dBc or better
DC to 6GHz
Low VSWR 1.15:1 Max
Low Insertion Loss
Op. Temp -65C to 105C

Description	ConductRF #	Stock Ref#
Din7/16 Male to Din7/16 Male	DDM11A-ADPWLP	376
Din7/16 Female to Din7/16 Female	DDF11A-ADPWLP	331
Din7/16 Male to Din7/16 Female	DDA11A-ADPWLP	377
Din7/16 Male to Din7/16 Female - R/A	DDA21A-ADPWLP	332
Din7/16 Female to Din7/16 Female - 45Deg	DDM21B-ADPWLP	387
Din7/16 Male to Din7/16 Female - 45Deg	DDA21B-ADPWLP	382
Din7/16 Male to N Male	BA-DDM-N5M-LP	378
Din7/16 Male to N Female	BA-DDM-N5F-LP	379
Din7/16 Female to N Male	BA-DDF-N5M-LP	381
Din7/16 Female to N Female	BA-DDF-N5F-LP	N/A
Din7/16 Male to 4.1/9.5 Male	BA-DDM-D4M-LP	N/A
Din7/16 Male to 4.1/9.5 Female	BA-DDM-D4F-LP	N/A
Din7/16 Female to 4.1/9.5 Male	BA-DDF-D4M-LP	394
Din7/16 Female to 4.1/9.5 Female	BA-DDF-D4F-LP	N/A
Din7/16 Male to 4.3/10 Male	BA-DDM-D3M-LP	N/A
Din7/16 Male to 4.3/10 Female	BA-DDM-D3F-LP	N/A
N Male to N Male	N5M11A-ADPWLP	396
N Female to N Female	N5F11A-ADPWLP	397
N Male to N Female	N5A11A-ADPWLP	N/A
N Male to N Female - R/A	N5A21A-ADPWLP	N/A



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