The UHF type connector under network analysis

A closer look at the non-constant Impedance PL-259 and SO-239.

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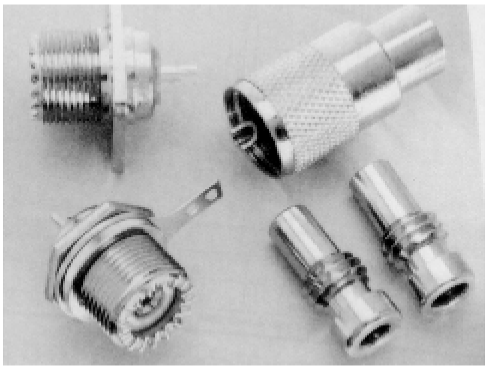


Introduction The UHF type connector saw its conception in the early 1930's, a time when VHF/UHF technology was quite new. The forefathers of VHF were in many cases Amateur radio experimenters, most with Engineering and technical backgrounds, they began experimenting and working the VHF frontier around 1926. Soon thereafter research into FM radio and Television began and out of this era came the then named UHF connector.

At this time the mathematical concepts and models of fields and waves were well defined by James Maxwell and others who followed Maxwell's work. However the problems encountered were of a physical nature as instrumentation and material sciences were developing at much slower rates. Results in this era of radio and communications were more often gained by the trial and error method of experimentation with measurements being made by instruments which would now be considered crude. This in actual fact is a credit to those who achieved so much at the time.

Aim In this short paper I will attempt to take a practical approach to demonstrate the problems associated with non constant impedance RF connectors. Of particular interest is the now inappropriately named UHF type connector, known more commonly as the PL-259 (Male) and SO-239 (Female). The results gained here are primarily aimed at supplying fellow radio amateurs with information that is not readily available. Characterisation will take place at frequencies around 146 MHz and the at UHF frequency of 438 MHz, where in actual fact this type of connector is not recommended for use.

Manufactures of UHF plugs and receptors all state that this type connector are of non-constant impedance and are suitable for use up to 200 or 300 MHz, depending on production quality. They also state that the UHF connector can be used up to 500 MHz with a cautionary note of reduced performance. A range of manufacturers specifications for the UHF type connector are included in appendix A. Connecters and adaptors used in this test are also included. Note: appendix A is not included in html version.

Method How do we evaluate the characteristics of a connector? Well, to start with we would need to measure the impedance. Having established this we could then find the insertion and return losses. How do we measure these parameters? The most widely used instrument and preferred tool for RF engineers is the Network Analyser. In this case I employed the use of the Royal Melbourne Institute of Technology's Wiltron model 360B Vector Network Analyser. This is a device that measures the magnitude and phase characteristics of RF networks, amplifiers, attenuators and antennas operating from 10 MHz to 40 GHz. It compares the incident signal that leaves the analyser with either the signal that is transmitted through a test device or the signal that is reflected from its input.

Procedure For this test I decided to simulate the amount of transitions that would be encountered in a transceiver to feedline, feedline to antenna situation, with the exception of the actual feedline. Further to this I will make a comparison with the N type constant impedance connectors using the same approach.

I used presicion 50 Ohm Test lines, 500mm in length, being terminated with APC-7's at both ends, so APC-7's to Male N types were added to each. The Network Analyser is calibrated with the 50 Ohm test lines and adaptors installed on each port using the supplied standards in the form of a 50 Ohm Cal Kit. A OPEN, SHORT and TERMINATION. Great care must be exercised with all cal kit components as they are quite expensive (around $1000AU ea).

UHF type adaptors used in comparison

2 x Female N to PL-259 Adaptors (simulating line connectors, PL-259's)

1 x Female UHF Barrel Connector (simulating radio and Ant, SO-239's)

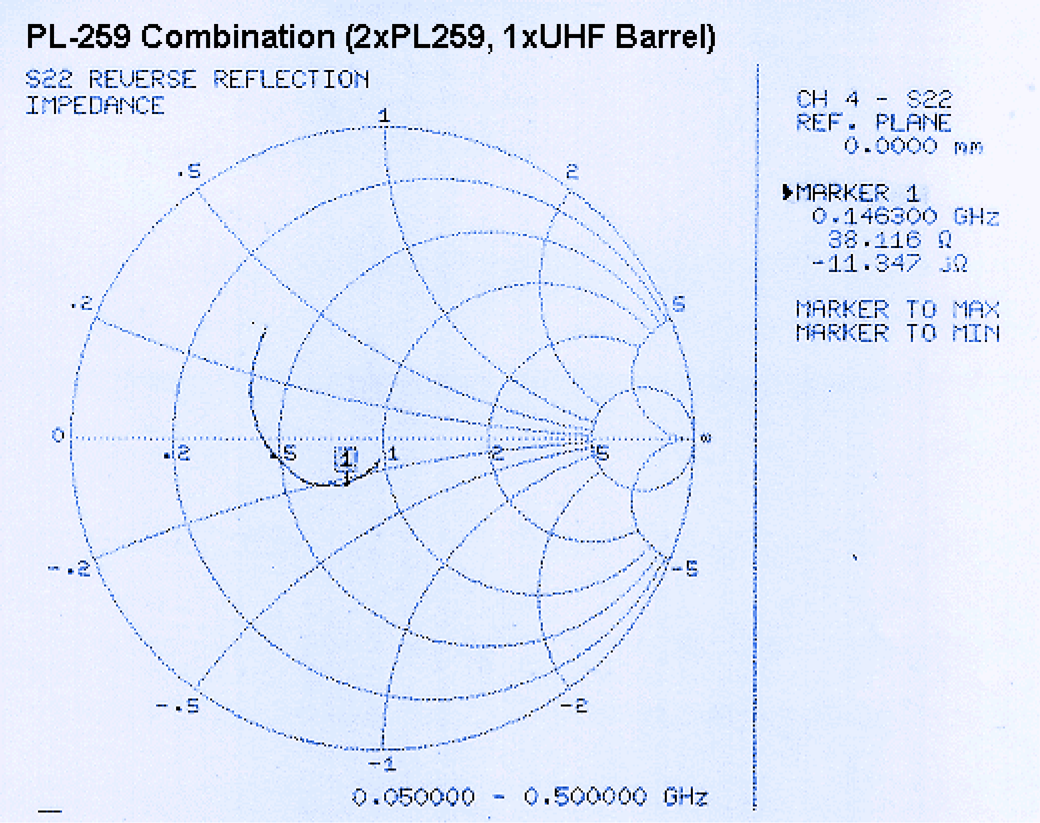
N type adaptors

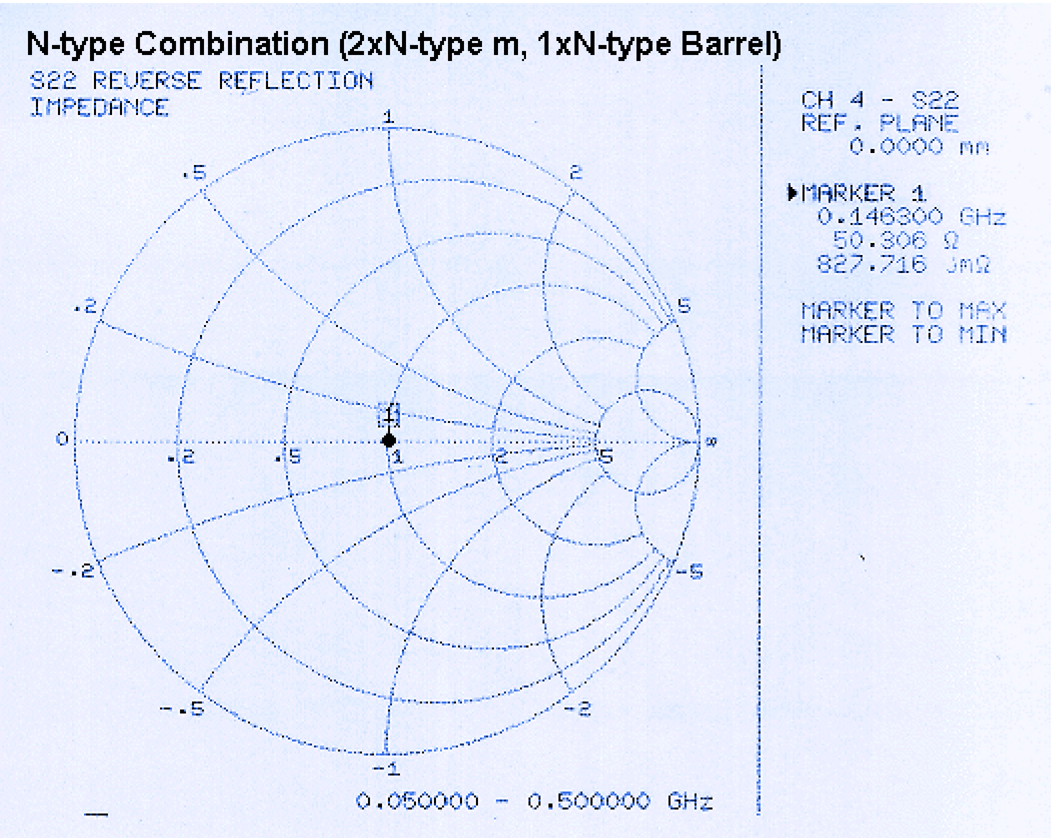
2 x Female to Male N Adaptors (simulating the line connectors,N Males)

1 x Female to Female N Adaptor (radio and antenna connections,N FM's)

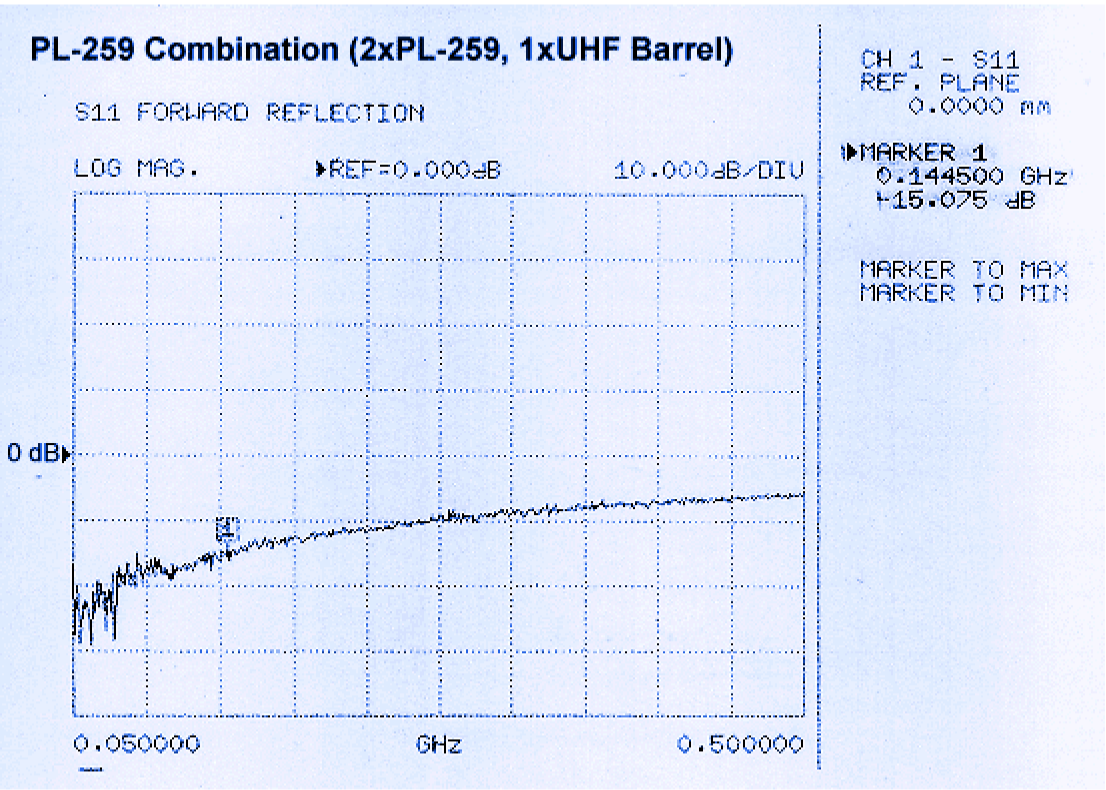
Results Two of the N to PL-259's were mated with a UHF (SO-239) barrel connector, this configuration then becomes the DUT for the UHF series of tests. A direct comparison is then made with an equivalent combination of N type adaptors from 50 to 500 MHz, thus the results are presented as such. It should also be pointed out that all figures stated are as displayed at the time of testing, for the sake of simplicity we will ignore system errors and associated calculations.

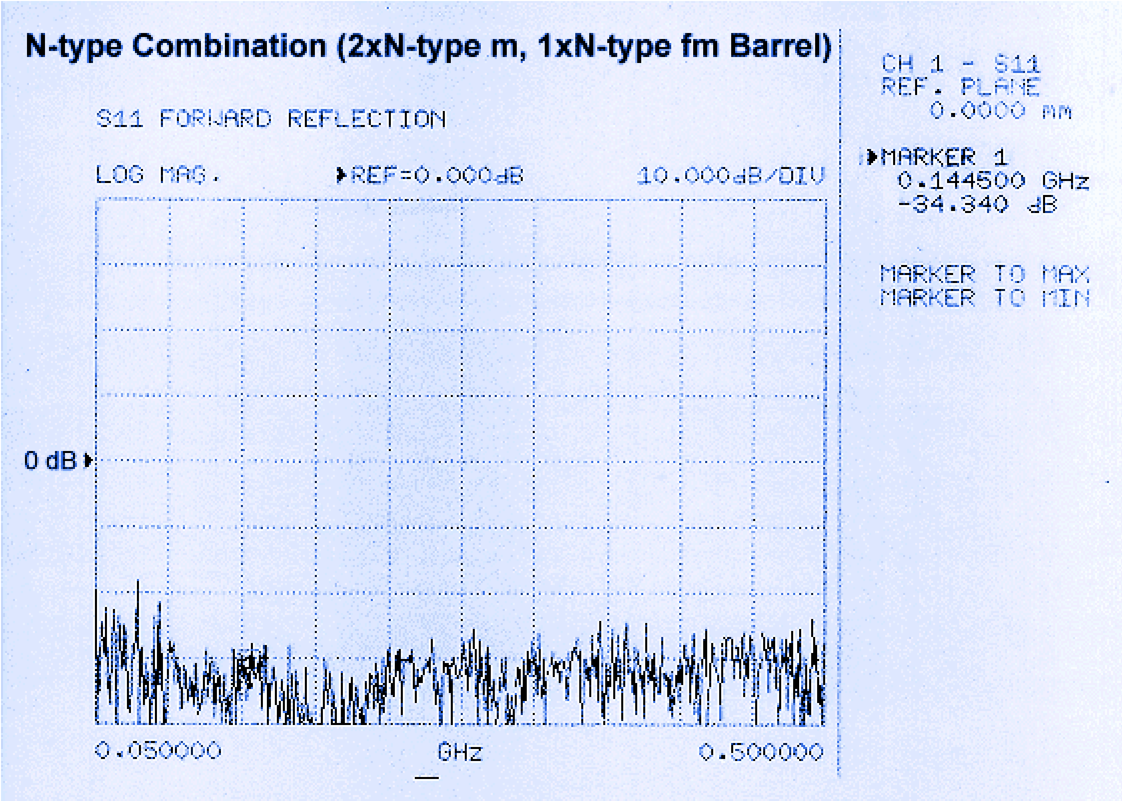
The first comparison is that of Reverse Reflection Impedance, this is known as a S22 Parameter. In short the closer this figure is to one on the real axis of a Smith Chart, the better the match is to 50 Ohms. Results shown on the 1st Smith Chart verify that the UHF connector is as the manufacturer's say, a non-constant impedance connector. At 146.3 MHz the Reverse Reflection Impedance of the combination is about 38 Ohms (ignoring the complex) at 432 MHz, the figure is almost 30 Ohms. Turning to Smith Chart 2 shows almost a perfect transition through the N type combination to 50 Ohms, right up to 500 MHz.



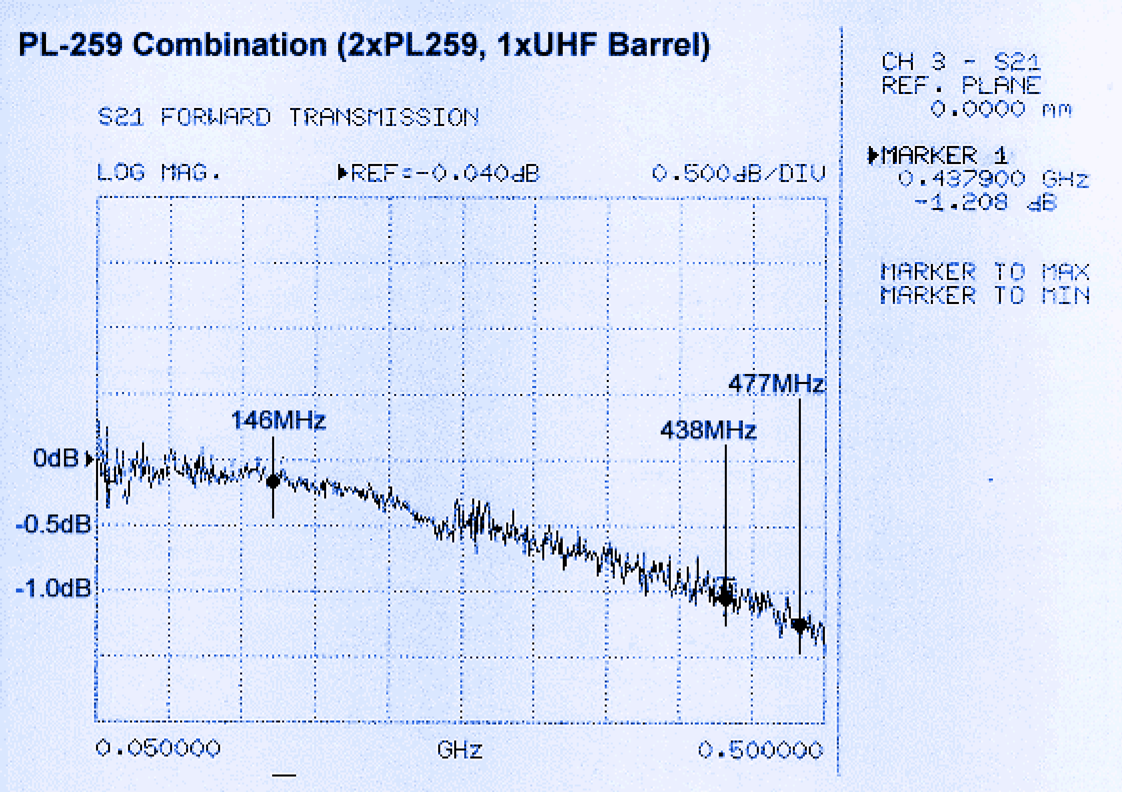


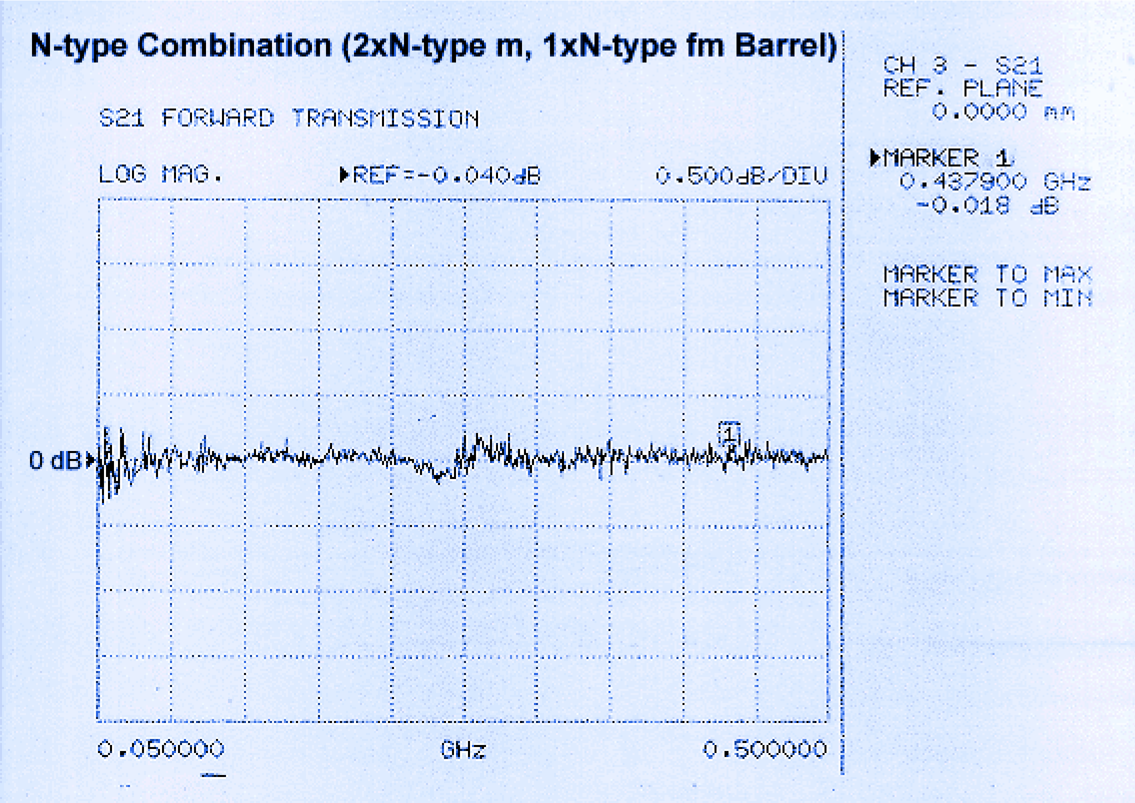
The next comparison was that of Forward Reflection or Return Loss known as a S11 Parameter. Return Loss is a measure of the dissimilarity between two impedance's. The Amplitude of the reflected wave to the amplitude of the incident wave, expressed as a ratio, normally in decibels and is measured at the junction of the transmission line and a terminating impedance. In an ideal model there would be no measurable return loss because the load would receive and absorb all of the transmitted power but in the real world this is not the case as no system is perfect. A very good transmission system would have a return loss of around -30 to -20dB at microwave frequencies. A return loss figure of -20 to -10dB is what may loosely be termed as the norm for a reasonable transmission system working at VHF to Microwave frequencies. Good connectors exhibit return losses on the order of -40 to -30 dB and as we can see on the PL-259 & UHF Barrel data, it's not quite within this range. Being at -15 dB for 146.3 MHz and a rather poor figure of around -8 dB at 432 MHz. On the next plot, we can see that the N type combination was fairly flat from 50 to 500 MHz, giving a much better result with return loss figures in the order of -35 to -30 dB across the same frequency range.





The final sets of comparison data is probably the most interesting to the VHF/UHF amateur being Forward Transmission or Insertion Loss known as S21 Parameter. This parameter is by name self explanatory and the comparison plots and data are presented on the last 2 sweep data plots. The Insertion Loss that we can see associated with UHF connector data is of course due to the non-constant Impedance transition. We can also see that this becomes more of a problem as frequency increases toward 500 MHz on the sweep data. At 144.5 MHz and 146.3 MHz the Insertion Loss runs around 0.2 dB, increasing to around 1 dB at 432 MHz. In comparison the Insertion loss for the N-type combination was very low, in fact almost immeasurable.





Conclusion Before wrapping things up I must admit that the UHF type barrel connector employed here was of fairly poor quality, as one would find in most hobby type outlets. I suspect that it contributed significantly to the poor results gained but we should also keep in mind that good quality connectors of the UHF type are not easily found. In real world terms the 0.2 dB Insertion loss at 144 MHz would be a transmission loss of more than 1 Watt from a 25 Watt input at 144 MHz. The real bad news is at 432 MHz where we see a loss in the order of 1.0 dB, this equates to a transmission loss of around 6 Watts with 25 Watts input. This phenomenon is of course due to the Impedance "bump", the power is not actually lost but reflected in the transmission lines.

Most of use have used a VSWR meter, a useful device for looking at reflected waves, a lot of these units also give a relative power reading. Perhaps at sometime or another you may have noticed some particularly strange indications while using your meter at VHF/UHF frequencies. The problem with this type of instrument is that it is both frequency and impedance sensitive. We can normally recalibrate for the frequency of operation but impedance is fixed at 50 Ohms, therefore any mismatches on the line both before or after the meter will cause error in the indicated parameters. As we can see from our test results of the UHF type connector the Impedance is non-constant and at VHF and UHF frequencies offers a varying mismatch to 50 Ohms. This in turn will cause error in both VSWR and Power readings particularly at UHF frequencies. A more detailed description of interpreting Antenna and line measurements directed particularly at the Amateur was written by R Bertrand VK2DQ in the mid 1980's, it can be found in the *Amateur Radio Action, Antenna Book 3.*

I would like to finish with these few points. The first being that the so named UHF connector from the past is not really suitable for use above 300 MHz at all. Perhaps the exception to this would be when a cheap and rugged system is required where loss and good signal to noise ratio is of little concern. Unfortunately it appears that both Amateur and CB Radio UHF type equipment fall into this category as many manufactures still supply SO-239 UHF receptors as standard equipment. The second point is that from our results we can see that utilisation of the UHF connector at 146 MHz for FM type transceivers is not such a problem. A cheap rugged connector is probably an advantage as many FM units are used for mobile applications. However, for 144 MHz SSB type work where low loss and good signal to noise ratio is very desirable, again I would not recommend the use of UHF type connectors. The UHF connector still has a place in many applications where a robust economical RF connector is required but for serious applications its use should be limited to below 100 Mhz. As we have shown the N type is far superior in performance, it should also be noted the BNC type connector is similar in performance to that of the N type but has the disadvantage of being less rugged. In the end, one should always check with the manufactures specifications.

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