and 3) impedance matching. It is found that the fluctuations of the output noise from this NBS solid-state noise source behave as a flicker noise process, and the square root of the variance of its noise output for one-day sampling time is 0.002 dB. In contrast, the fluctuations of the output noise from the typical commercial solid-state noise source behave as a random walk noise process, and the square root of the variances for its output noise for a one-day sampling time interval is about 0.008 dB. Thus the stability of the NBS solid-state noise source is improved significantly over that of typical commercial solid-state noise sources.

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A New 34-GHz 3.5-mm Low-Cost Utility Coaxial Connector Featuring Low Leakage, Low Standing-Wave Ratio, and Long Life

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***Abstract*—A utility 3.5-mm connector was designed to cover frequencies above 18 GHz in coaxial transmission lines. The superior cost/performance characteristics of this new connector are presented.**

Introduction

During the late 1950's to early 1960's, the 7-mm coaxial transmission lines with their standard type N connectors were only used to 10 or 12 GHz. With the advent of the precision 7-mm sexless connectors during the first half of the 1960's, the APC-7 and the Precifix A connectors, the frequency range was extended to 18 GHz, which is the practical limit for 7-mm transmission lines. Concurrently, the type N connector went through a redesign phase to cover the same frequency range as the sexless 7-mm connectors. The ever-expanding use of these frequency ranges with requirements of broader bandwidths and new frequency allocations assigned in the U.S. by the Federal Communications Commission and in Europe and other parts of the world by their appropriate agencies, made it quite necessary to extend the useful coaxial instrumentation beyond 18 GHz. For many narrow-band applications, waveguides were already used, but allocations in some cases assigned bands on overlapping band edges.

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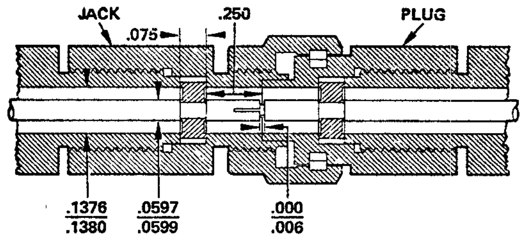


Fig. 1. Cross section of the connectors mated and as assembled on to center and outer conductors.

In the mid 1960's the U.S. Department of Commerce established the Joint Industry Research Committee for the Standardization of Miniature Precision Coaxial Connectors (JIRC/SMPCC). The result of that effort yielded a voluntary product standard in 1972. The air transmission line size was reduced to 3.5 mm to extend the mode-free operation of that line to 36 GHz. A hermaphroditic connector was also proposed, which has been available for years now, and was submitted for standardization to the International Electrotechnical Commission through Technical Committee 46D. These connectors perform quite well; however, due to their high precision, their price tag prohibits them from gaining acceptance for wide usage as a utility connector. The need was clear to design a utility 3.5-mm high-performance low-cost coaxial connector.

Many mechanical properties were considered in the design of this connector (Fig. 1). An objective was to build on experience gained from the use of other RF connectors. An example, the mating surface of the outer conductor on the male connector has a wall thickness of 0.020 in. This relatively thick wall will withstand high contact force insuring good connector repeatability, long life, and low leakage.

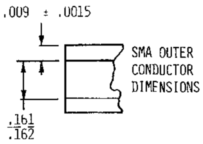
The recessed bead has several advantages. The impedance of the transmission line at the connector interface is controlled by only two parameters, that is, the diameters of the center and outer conductors. A sufficiently large spacing between the beads of the connector mated pair was chosen to allow resonance-free operation to 34 GHz. Any higher order modes that may be generated at the transmission lines support (bead) will die out rapidly, and not cause a resonance problem [1]. With air as the interface dielectric there are none of the plastic-filled connector problems such as, 1) an air gap length that is hard to control and can change with temperature, and 2) a line impedance that also depends on the plastic's dielectric constant and dimensions. The additional benefits to the user are that the line impedance can be established by two simple physical measurements and that the performance of any mated pair of these connectors will be very similar.

The material used for center and outer conductors is gold-plated BeCu. This material is used to assure the highest contact pressure and electrical conductivity and is a nonferromagnetic material. Long wear, low loss, and low leakage as well as less susceptibility to damage are the results of using this tough material.

Table I shows the dimensions of an SMA connector outer conductor detail with its tolerances. Minimum and maximum areas of outer conductor contact surfaces are calculated. Maximum allowable compressive loads are calculated from yield strengths taken from available reference data showing stainless steel being inferior to half and full hard BeCu. Furthermore, thread load was calculated using SMA connector specifications, which indicates approximately a 165-lb load applied by

TABLE I
COMPARISON OF OUTER CONDUCTOR MATERIALS

CONTACT AREA: $\frac{\pi}{4}(D^2 - d^2)$



$A_{MIN} = 39.9 \times 10^{-4}$ IN^2
$A_{MAX} = 56.6 \times 10^{-4}$ IN^2

MAXIMUM ALLOWABLE COMPRESSIVE LOAD P = AS

	P_{MIN}	P_{MAX}
#303 STAINLESS STEEL	140 LB	198 LB
½ HARD BeCu	300 LB	424 LB
FULL HARD BeCu	658 LB	934 LB

S = YIELD STRENGTH
$S_{STAINLESS\ STEEL} = 35 \times 10^3$ PSI
$S_{1/2\ HARD\ BeCu} = 75 \times 10^3$ PSI
$S_{FULLHARD\ BeCu} = 165 \times 10^3$ PSI

THREAD LOAD: $Q = F \frac{2\pi r - \mu P}{P + 2\pi \mu r} \frac{R}{r}$

FOR SMA CONNECTORS WITH ¼ - 36NS THREADS, 10 IN LB TORQUE

Q = 190 LB

WHICH YIELDS WITH 60° THREADS

Q' = 165 LB LOAD APPLIED BY THE CONNECTOR NUT

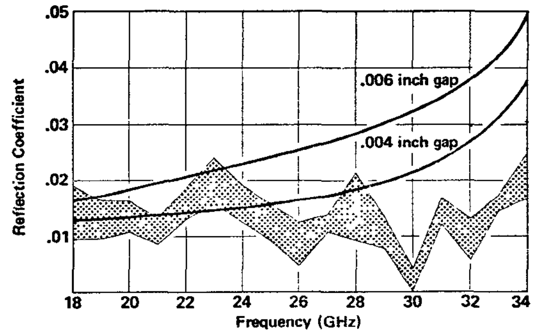


Fig. 2. Reflection coefficient as a function of frequency for several samples of single beads with a gap of 0.002–0.003 in between the full diameters of the male and female center conductors (dotted area). The two other curves represent the reflection due to gap only, for 0.004- and 0.006-in gap.

TABLE II
CONDITIONS AND RESULTS OF CONNECTOR PAIR LEAKAGE TEST

FREQUENCY	TEST METHOD			DYNAMIC RANGE	CONNECTOR TIGHTENING TORQUE	CONNECTOR BENDING MOMENT	RESULT
	SPECTRUM ANALYZER	MODULATED SUBCARRIER	DOUBLE CONVERSION				
0.1 GHz	X			110 dB	.8NM (7 in-lbs)	0	FOR ALL MEASUREMENTS, UNDER ALL TORQUE AND BENDING MOMENT CONDITIONS, NO DISCERNABLE CHANGE IN SYSTEM NOISE LEVEL WAS OBSERVED.
2	X			100	.8NM (7 in-lbs)	0	
3	X			100	.8NM (7 in-lbs)	0	
4	X			100	.8NM (7 in-lbs)	0	
6	X			100	.8NM (7 in-lbs)	0	
8	X			100	.8NM (7 in-lbs)	0	
8.0			X	148	.8NM (7 in-lbs)	0	
10	X			95	.8NM (7 in-lbs)	0	
12	X			95	.8NM (7 in-lbs)	0	
14	X			95	.8NM (7 in-lbs)	0	
16	X			90	.8NM (7 in-lbs)	0	
17.9			X	138	.8NM (7 in-lbs)	0	
18 to 26.5		X		100	.6NM (5.3 in-lbs) .8NM (7 in-lbs) 1.1NM (10 in-lbs)	1NM (8.85 in-lbs) 0 0	

the nut to that surface. This shows clearly the reason behind choosing BeCu for the outer conductor material, although the APC-3.5 connector has four times the area as that of the SMA.

The connector assembly consists of the center conductor, outer conductor, and bead. It is designed to be used with a 3.5-mm transmission line terminator [2]. Devices designed with the terminator make selection and use of any of the available connectors possible.

INTERFACE WITH OTHER CONNECTORS

Even though this connector is a true 3.5-mm airline type which operates to 34 GHz, it will also mate nondestructively with SMA series connectors. Within the frequency band of the SMA connector, the standing-wave-ratio (SWR) performance of this 3.5-mm utility connector/SMA interface is similar to the interface SWR of a mated pair of SMA connectors. In addition, connections to 0.141-diam semirigid coaxial cable can be made with existing connectors.

PERFORMANCE

As discussed previously, the connector was designed to provide excellent repeatability, long life, and low leakage. Since the diameter tolerances of the center and outer conductor are closely held, the major sources of SWR are the bead and the short section of the high-impedance transmission line formed by the gap between the full diameters of the male and female pins at the connector interface. Fig. 2 shows measured data of the magnitude of these SWR sources in the 18–34-GHz frequency range. Measurements of mated pair SWR and SWR repeatability have also been made [3].

Measurement Techniques Applied

A special computer-controlled network analyzer was built to extend its measurement capability to 26.5 GHz in order to allow evaluation of the transmission and reflection characteristics of this new connector. A special slotted line was also constructed to measure the bead reflections up to 34 GHz using Sanderson's technique [4]. Furthermore, tuned waveguide reflectometers with waveguide–coax adapters were utilized to verify measurement results taken by the aforementioned techniques.

Insertion loss and repeatability measurements are taken with the automatic network analyzer to 26.5 GHz and above 26.5 GHz with detectors and ratio-measuring equipment.

Leakage tests of a connector pair were measured at frequencies up to 26.5 GHz. A triaxial test fixture was built that is similar to the fixtures described in [5] and [6]. It was built so that a bending moment could be applied to the 3.5-mm connector. Cutoff frequency of this triaxial fixture for the TE_{11} mode is about 6 GHz.

Three test setups were used in the leakage test. First a standard spectrum analyzer setup was used. The dynamic range and frequencies of these measurements were from 110 dB at 100 MHz to 90 dB at 16 GHz. The second test method used a waveguide setup in K band similar to the modulated subcarrier described in [5]. The leakage test was performed across the full waveguide band from 18 to 26.5 GHz. The dynamic range of this test was 100 dB. The third test method was a double conversion setup using three synthesizers operating in a screen room from a common 10-MHz reference oscillator. The bandwidth of the measurement was 1 Hz yielding excellent test capabilities. Measurements were made at two frequencies—at 8 GHz the dynamic range was 148 dB; at 17.9 GHz it was 138 dB.

The swept measurements from 18 to 26.5 GHz were made under several conditions. The condition most likely to show leakage was: coupling nut tightened to 0.6 Nm with a 1-Nm bending moment applied to the outer conductor per [7]. The result of all measurements of leakage was that no discernable change in system noise level was observed (see Table II). Connector pair leakage was below the dynamic range of all measurements.

Conclusion

This connector has distinct advantages in performance and price as described previously. Furthermore, it is directly compatible with the most widely used SMA connector.

Acknowledgment

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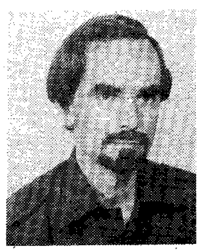
Contributors



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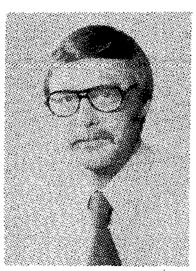

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