Directional Couplers / SWR detectors for 145MHz - 435MHz.

<< Easily and cheaply made. pa0nhc. Ver. E4; 2003 10 03. http://www.qsl.net/pa0nhc

PCB masks now also available in PDF.

Several years ago, i needed an SWR-meter/power-meter for use on 145MHz. As money was short, a cheap one ("Made in Italy") for 27MHz was purchased, as specifications stated is was "designed" for up to 150MHz.

Well, it was rubbish of cause. In the back, soldered on two SO239 receptacles, was a SINGLE sided PCB with some sharply zigzagging tracks and loosely connected wires, using the back plane of the housing at 5mm distance as a "ground plane". This could never result in a proper impedance of the measuring lines, even on 27MHz. The SWR (reflection damping) of this PCB itself was bad on 2mtrs, and power indication was a laugh.

In an old ARRL handbook was a picture of a PCB for use in a SWR-meter. Antenna books described how to make measuring lines from coax or using Toro ides. I tried some of these, but none of them was working properly on VHF, and descriptions did not say what the influence was of the coupling-wires, or the PCB-material on the properties of the whole thing. But i did found details about impedance of PCB-tracks, and decided to try to design my own directional coupler PCB.

Important for construction:

The width of the tracks and the dielectric constant of the PCB material determine the characteristic impedance of the tracks. Therefore, only use PCB with the specified dielectric constant. I was surprised to see that good quality hard-paper PCB (Conrad Electronics) had also the correct dielectric constant. But better use glass-fiber PCB as this is stronger.

The standard RF source- and load impedance of VHF/UHF communication equipment is 50 ohms. The power-line between the input and output connectors of a directional coupler therefore MUST have also that impedance of (exactly) 50 ohms.

The impedance of the measuring lines could have any practical value, as long as one side of each measuring line is terminated with the characteristic impedance of that measuring line.

The back plane of the PCB serves as mass plane and screen. Very short mass connections between receptacles and back plane are a MUST.

If the coupler is to be used as a directional coupler with HF-output from the measuring lines into 50 ohms loads, the measuring lines MUST have an characteristic impedance of 50 ohms as well.

It then is very easy to terminate those measuring lines correctly with resistive 50 ohms loads, made from 3x 150 ohms SMD resistors in parallel. If 90 degr. corners in the tracks are changed to 2x 45 degr; the unit can be used on 450MHz and even higher frequencies, as those corners do not reflect RF-waves back to the source anymore. This makes it easy to construct good performing instruments.

The output of a measuring line (sensitivity) depends on the wavelength of the signal, the length of the coupling line, and the spacing between the coupling line and the power line. 3x higher frequency means 3x higher output from the same configuration. If one PCB should be used for two different frequency bands, the sensitivity should be calibrated for each frequency band separately by trim potentiometers, if one scale is to be used on the meters. For higher frequencies (23cms) the coupling lines should be made shorter. For a low power range, a separate scale should be made to compensate for detector diode non-linearity.

The diodes should have low knee voltage, and suitable for high frequencies. Resistors and condensers are SMD types. Resistors should be soldered on top or beside each other, making good thermal contact to the PCB-tracks. Maximal power handling is determined by the maximum allowable power dissipation of the terminating SMD-resistors.

The coupling between the power line and measuring lines can be adjusted by varying the distance between them. This distance is critical, and care should be taken when photographing and etching the PCB. A coupling attenuation of less than 20dB will influence the SWR of the power line.

For testing the quality of the PCB-production process, a test picture is shown on the bottom of this document.

Possible uses.

1 Attenuator in conjunction with a standard dummy load, to measure the spectrum of a transmitter, using a receiver or spectrum scope.

2 Weak, influence-free coupling of a signal source onto a signal line.

3 Return loss measurements, using microwatts from a signal generator and a receiver, up to 50W transmitters.

4 Measurements on receiver sensitivity and transmitter sideband noise of a fully operational full duplex repeater.

4 Power- and SWR measurements, connected to a DC metering circuit.

5 Background monitoring and automatic adjustment of power output and load match.

Performance.

Tests on finished couplers showed nearly NO reflected power at 25W input, when terminated with a good dummy load.

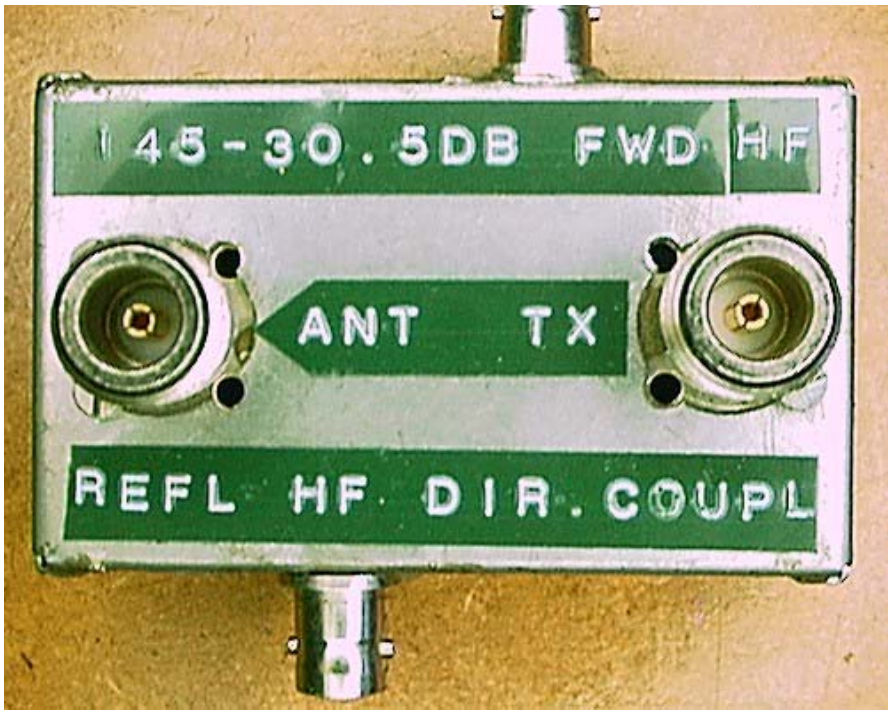
Tests on the directional coupler with HF-output clearly showed differences in reflection damping between different types of low power 50/51 ohms terminating resistors and dummy loads. Good terminators showed over 20dB return loss.

Such a directional coupler with HF-output can be used to measure the match of filters, conveniently using only microwatt-power, from a simple signal generator. A high power transmitter is not needed (see "band pass filters for 145MHz").

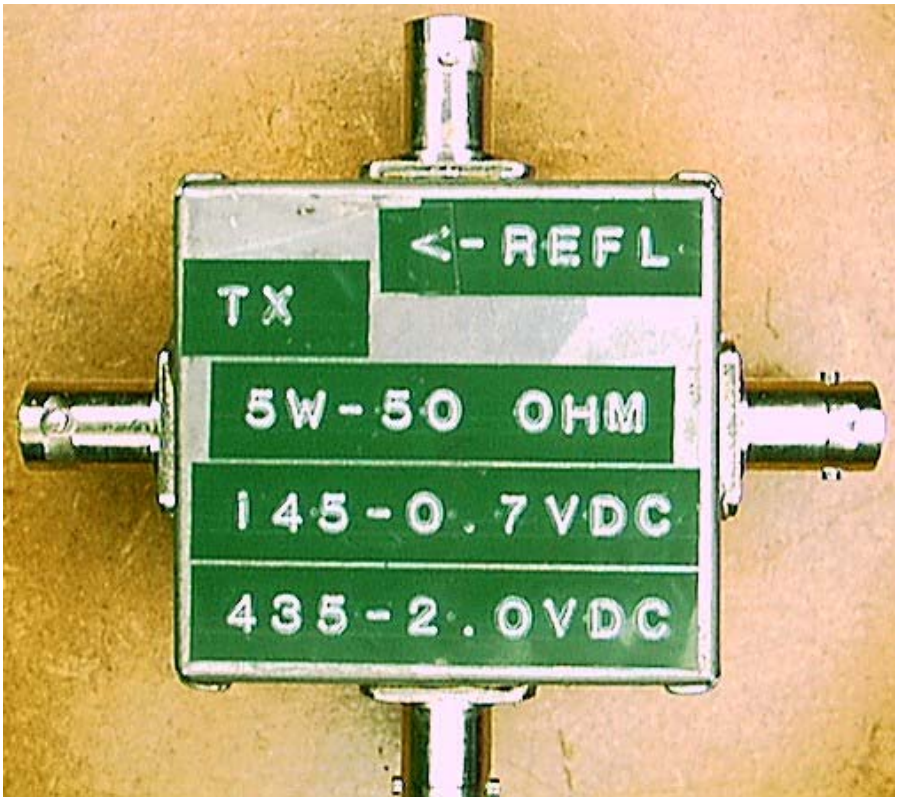
A/B port	25W	2,5W	0,25W
145MHz:	(V)	(V)	(V)
A fwd.	1,91	0,520	0,070
B fwd.	1,90	0,52	0,065
A refl.	0,039	0,0038	0,0001
435MHz:			
A fwd.	5,28	1,475	0,33
B refl.	0,300	0,0485	0,0043
A refl.	0,361	0,057	0,005

It also showed to be ideal in use for sensitivity measurements on our repeaters, which were working in full duplex mode on a dummy load or a antenna. The attenuation (coupling loss) from repeater-transmitter to the signal generator was -20dB to -30dB, so the signal generator could not be damaged, and could not cause IMD. Real sensitivity measurement of a fully operational repeater, without the use of an expensive measuring set, then is easy.

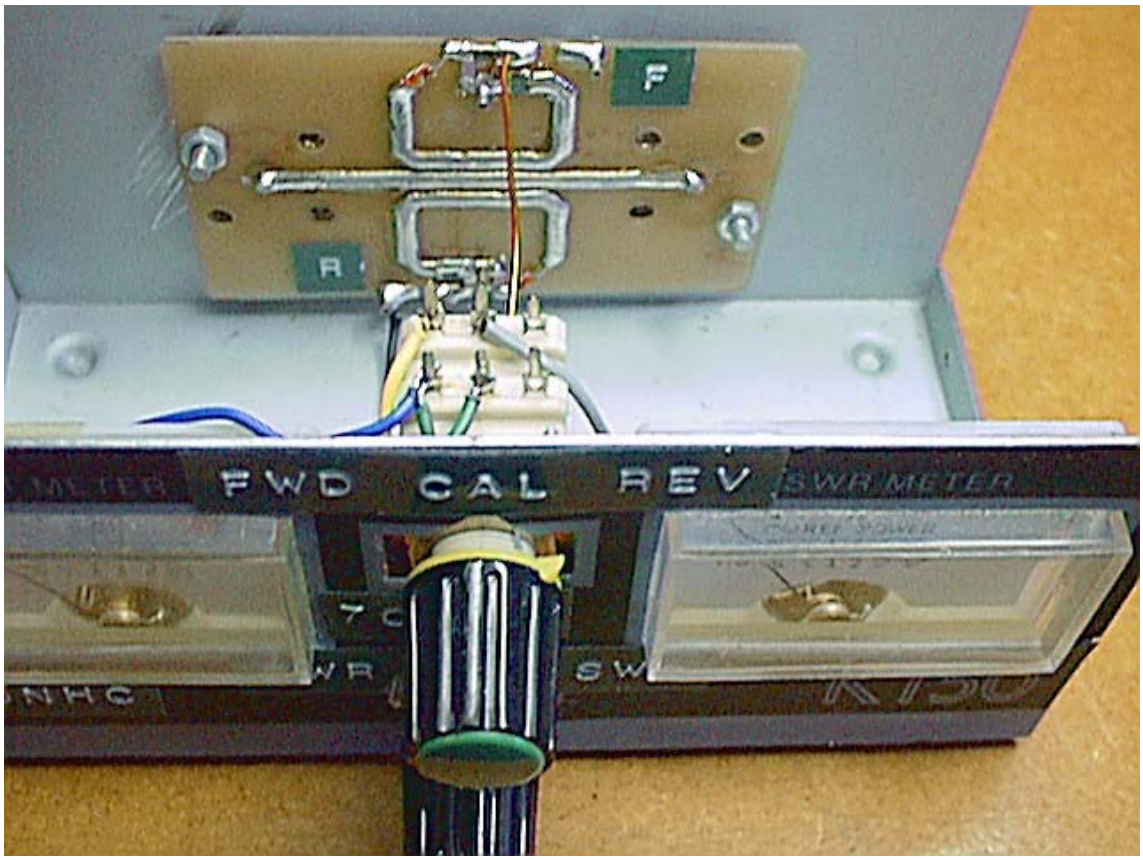
Pictures of prototypes:



Directional coupler with HF-output, -30,5dB @ 145MHz, -20dB @ 435MHz.
This unit is useful for weak coupling of HF-sources, and return loss measurements with very low to high power.
The housing is a very small TEKO box, seen onto the bottom.



Directional coupler with detectors and DC-output.
This unit can be used as power meter and SWR meter for 28MHz to 435MHz.
The housing is a very small TEKO box, seen onto the bottom.



Directional coupler with detectors and DC-output,
replacing the poor detector circuit in a citizens band "power/SWR meter".

It now can be used to measure on 28MHz, 145MHz and 435MHz.

Sensitivity of the SWR-metering is: 145MHz/5W, 435MHz/1W.
Full Scale Deflection for power measurements was adjusted to 10W.

As shown here, a simple but accurate PCB works, with the on-soldered receptacles screwed to the back of the housing.
On the top of the PCB can be seen: the diodes, and the SMD filter-C's and resistors. Just to the right of the wire, the terminating resistor is visible, 3 resistors of 150 ohms in parallel.
The rivet connects the "mass" island the the signal-mass-plane at the back.

"Forward" output and "Reflected" output are connected to separate meters. A switch is used to calibrate the "Forward" meter for full scale deflection on 145MHz or 435MHz when used as a power meter. When used as an SWR meter, the double potentiometer is used to adjust both meters for Full Scale Deflection in the "forward" direction.

But, to prevent radiation of HF power, better put the PCB in a HF-tight box, with DC-outputs to the metering circuits filtered.

The detector circuit alone could be used as a part of a transmitter output circuit, to monitor and automatically adjust power output, and monitor mismatch by a load, then automatically reducing the output power to a safe level.
In an automatic tuning unit it could provide the needed measuring voltages.

Note: all PCB's are double sided copper clad, **dielectric constant=4.35 , quality class fr3 or fr4** (Conrad electronics). The back plane is all copper, and it must be soldered to mass connections on the front plane (see markings) through the rivets. The dimensions are designed to fit rugged, small, HF-tight TEKO steel sheet housings (www.barendh.nl).

Drawings are accurate and sharp, with outer dimensions stated. The PCB must be photographed and etched accurately, as the dimensions are of direct influence on the correct impedance of the lines, thus on accuracy of the instrument.

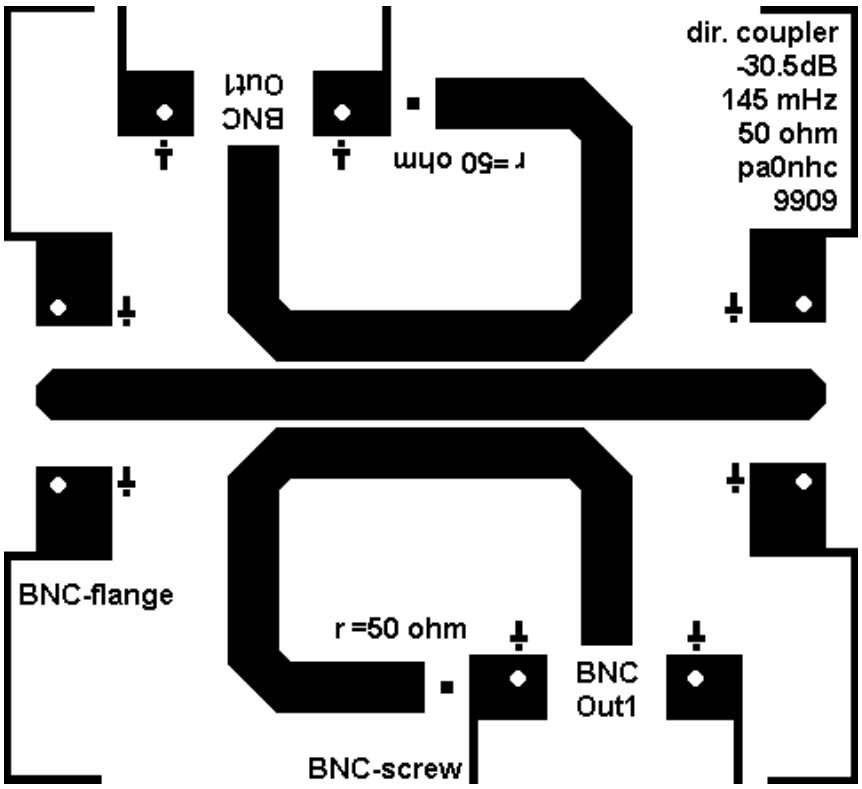
To adjust and check the producing results, a "test" pattern is provided.

The output of the measuring lines is on 435MHz 3 times higher than in 145MHz, and 15 times higher than on 29MHz.

For low power ranges, meter scales should be separately calibrated per frequency band.
For 28MHz, the coupling lines could be made longer to increase output.
For 1.2GHz, the coupling lines should be made shorter.

Directional couplers with HF-output, PCB's of different types for different connectors and casings.

BNC receptacles are of screw-type. Casings from TEKO.
N receptacles are of flat flange-type, with the flange directly soldered onto the bank plane of the PCB, and then screwed into the back plane of the box.
Solder the back plane of the PCB on marked places to the component side via the rivets.
The "50 ohms" terminating resistors comprises each of 3 SMD resistors 150 ohms in parallel.
The PCB tracks are soldered directly under the center-pins of all BNC's.
Solder the the mass-connections of the PCB to the nuts of the BNC receptacles, not to the box itself.



PCB 48x44mm, BNC receptacles on sides.

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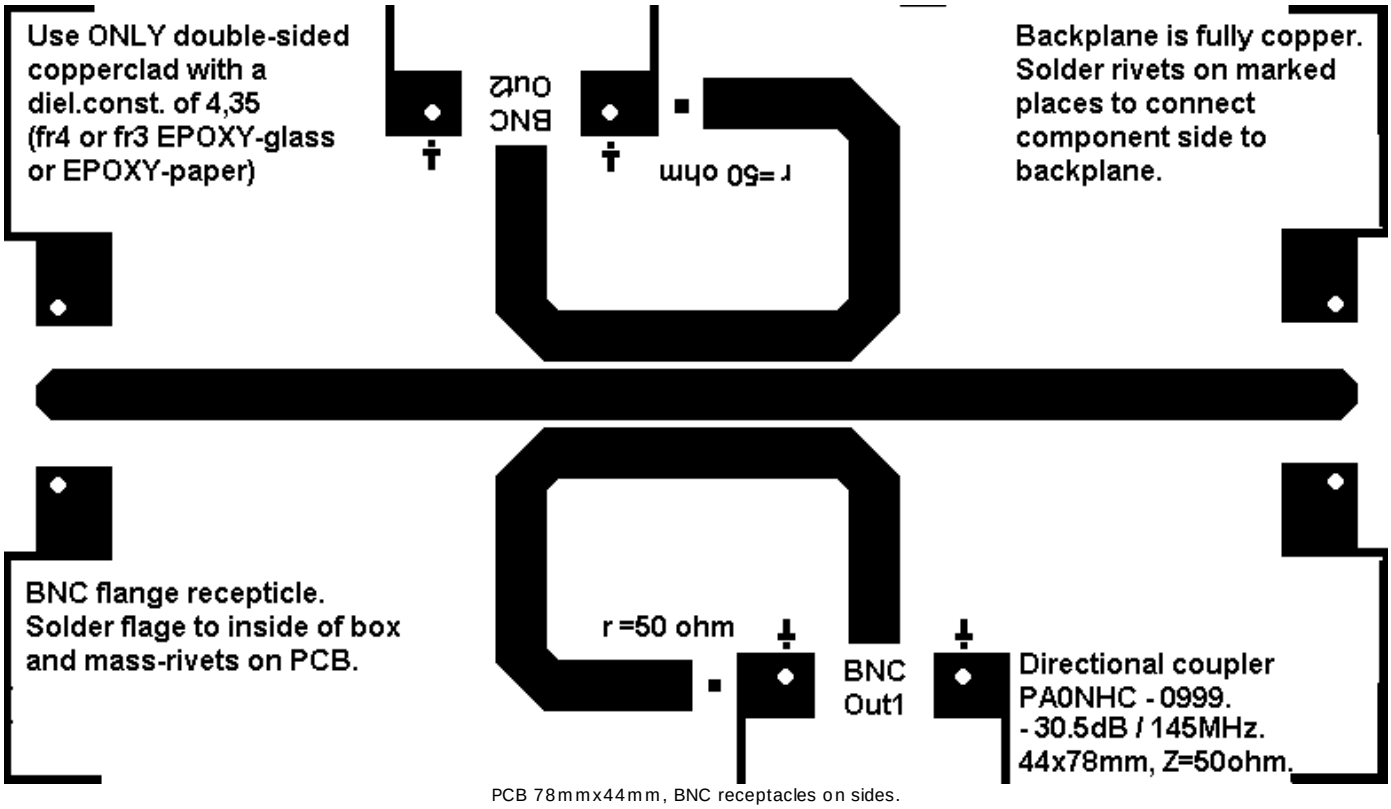

PCB 78mmx44mm, BNC receptacles on sides.

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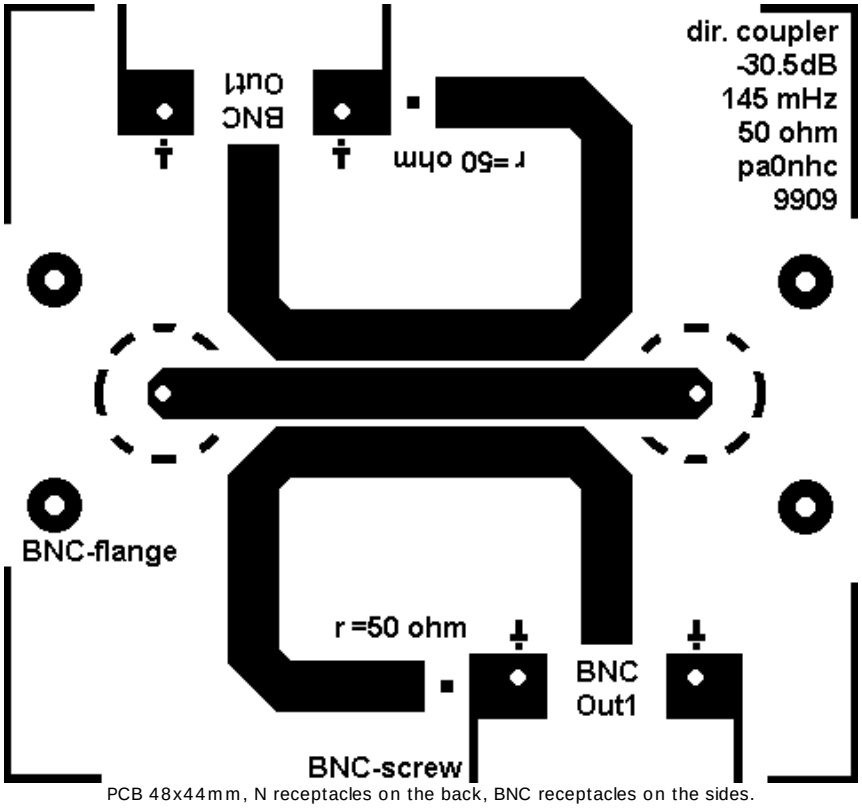

PCB 48x44mm, N receptacles on the back, BNC receptacles on the sides.

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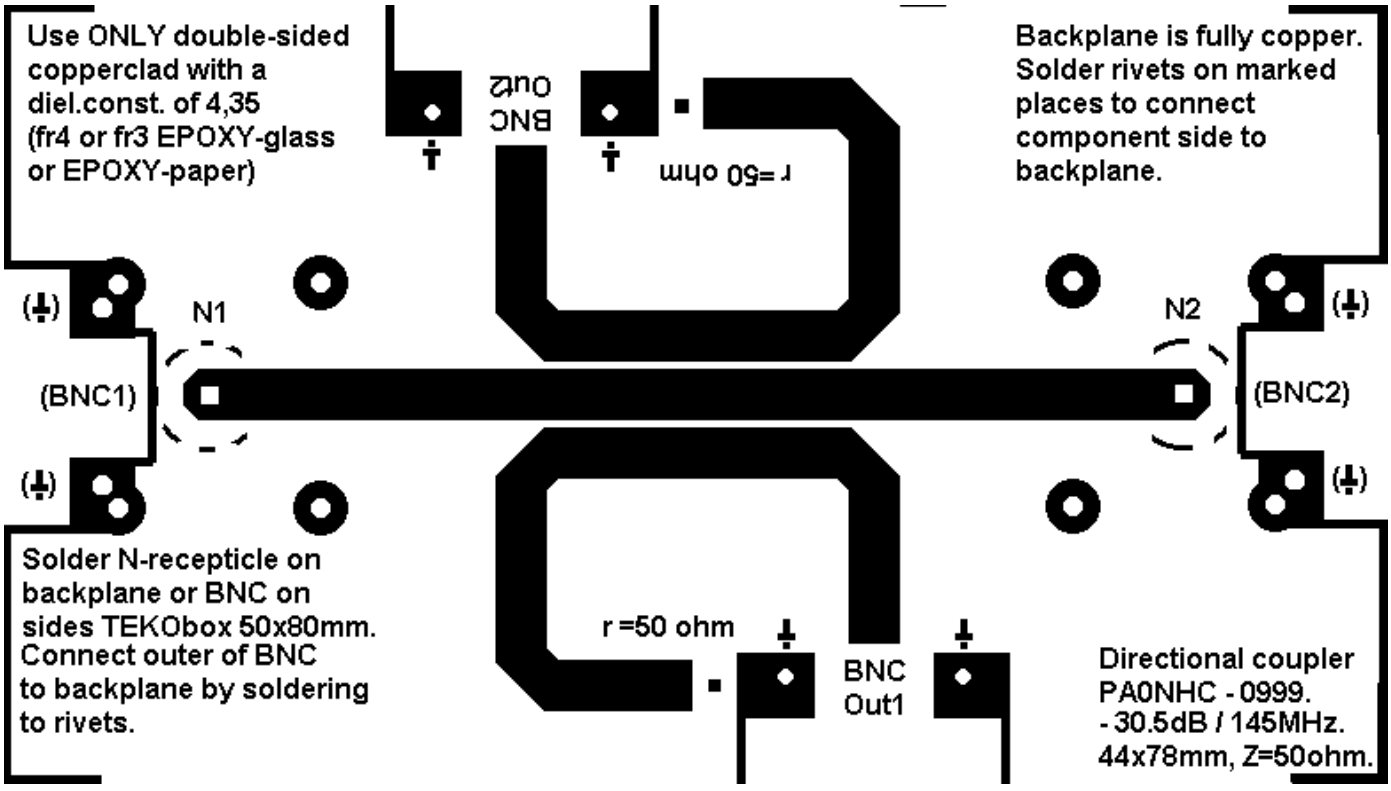

Universal PCB 48x44mm, BNC receptacles on all sides, or N-receptacles on the on the back.

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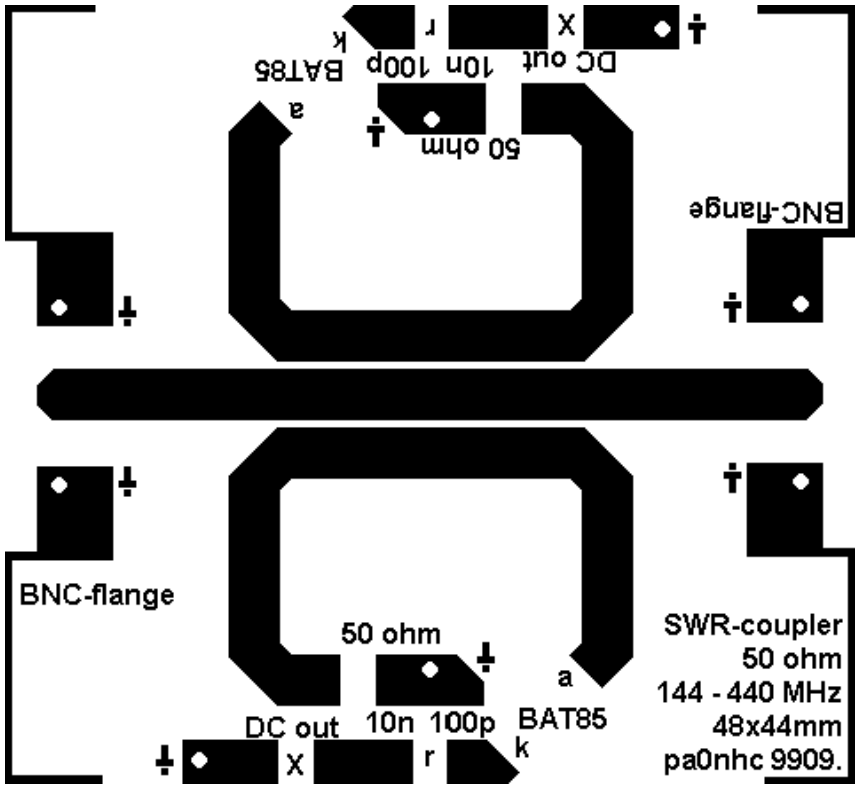
Directional couplers with DC-output for use in SWR / power meters, PCB's of different types for different connectors and casings:

BNC receptacles are of screw-type. Casings from TEKO.
N receptacles are of flat flange-type, with the flange directly soldered onto the bank plane of the PCB, and then screwed into the back plane of the box.
Solder the back plane of the PCB on marked places to the component side via the rivets.
The "50 ohms" terminating resistors comprises each of 3 SMD resistors 150 ohms in parallel.
The PCB tracks are soldered directly under the center-pins of all BNC's.
Solder the the mass-connections of the PCB to the nuts of the BNC receptacles, not to the box itself.

Reverse the diodes if negative DC output is wanted.
The RF-filters in the DC-outputs comprises of SMD-components: at the diode 100pF to mass, r=150 ohms in series, and 10nF to mass at the output.
X= The output connection to BNC receptacles, or to feed-through-Cs and external screened wires.



PCB 48x44mm, BNC receptacles on sides.

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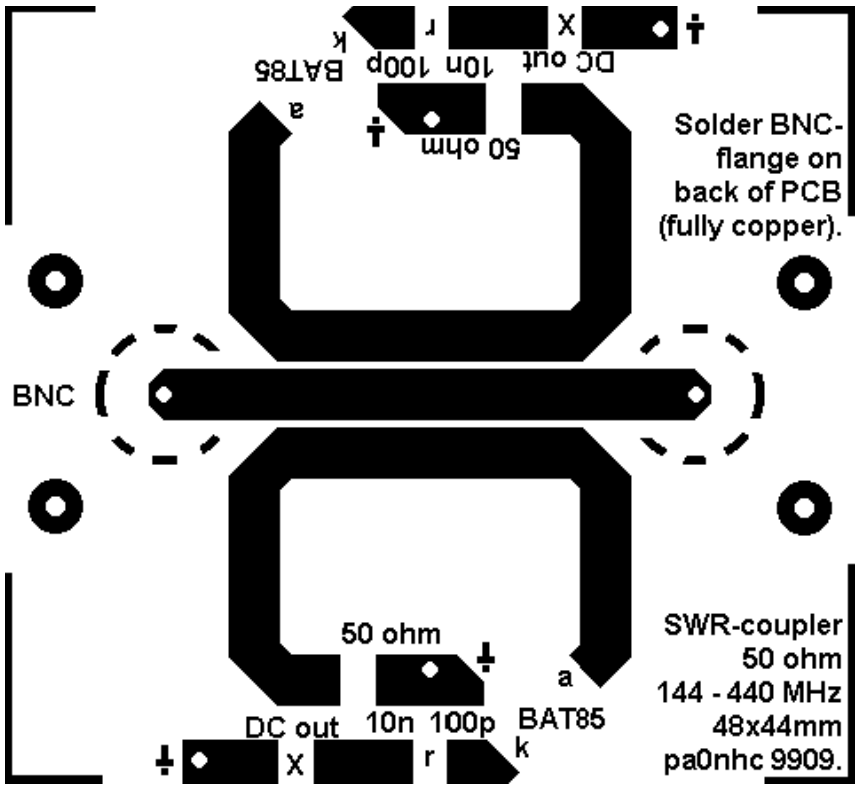

PCB 48x44mm, HF power on N-receptacles on the back, DC output BNC receptacles on sides.

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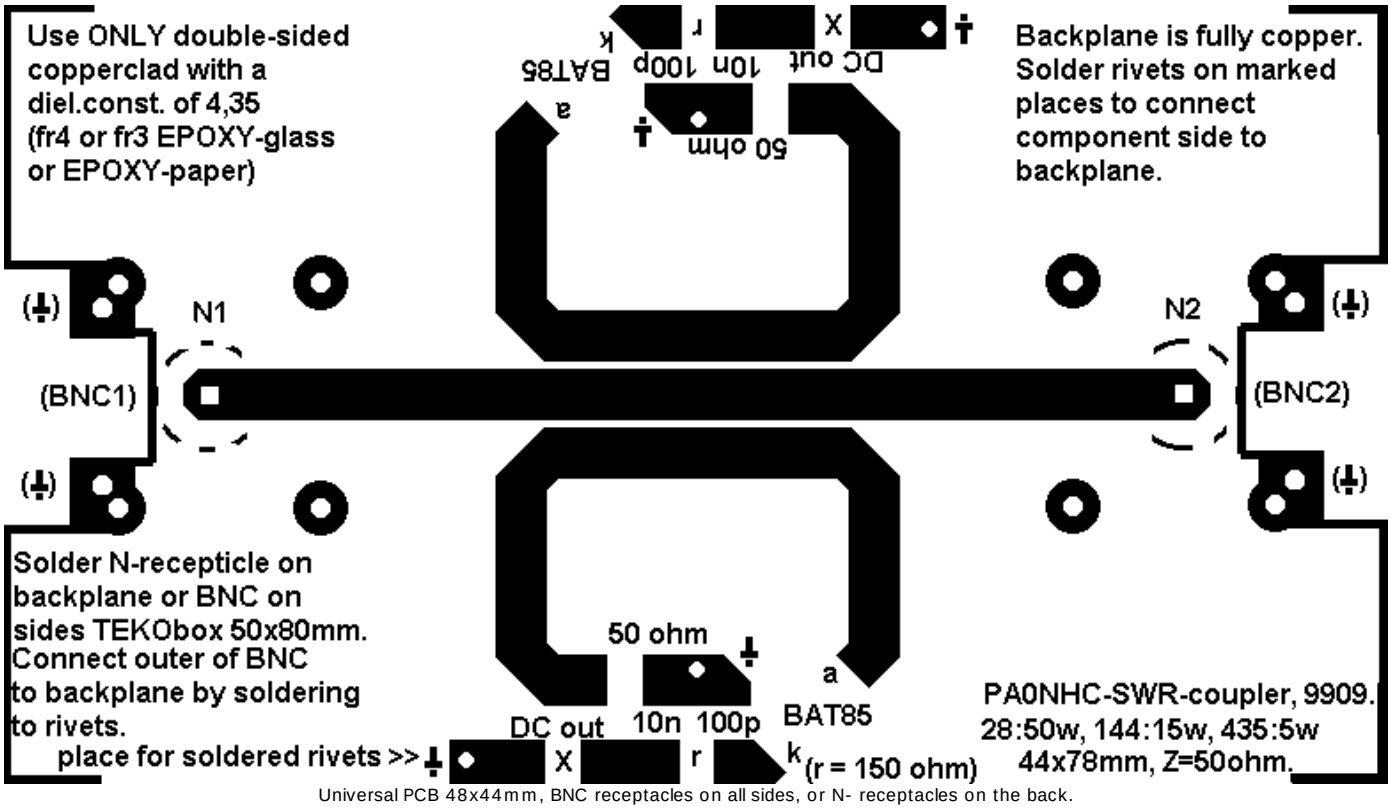

Universal PCB 48x44mm, BNC receptacles on all sides, or N- receptacles on the back.

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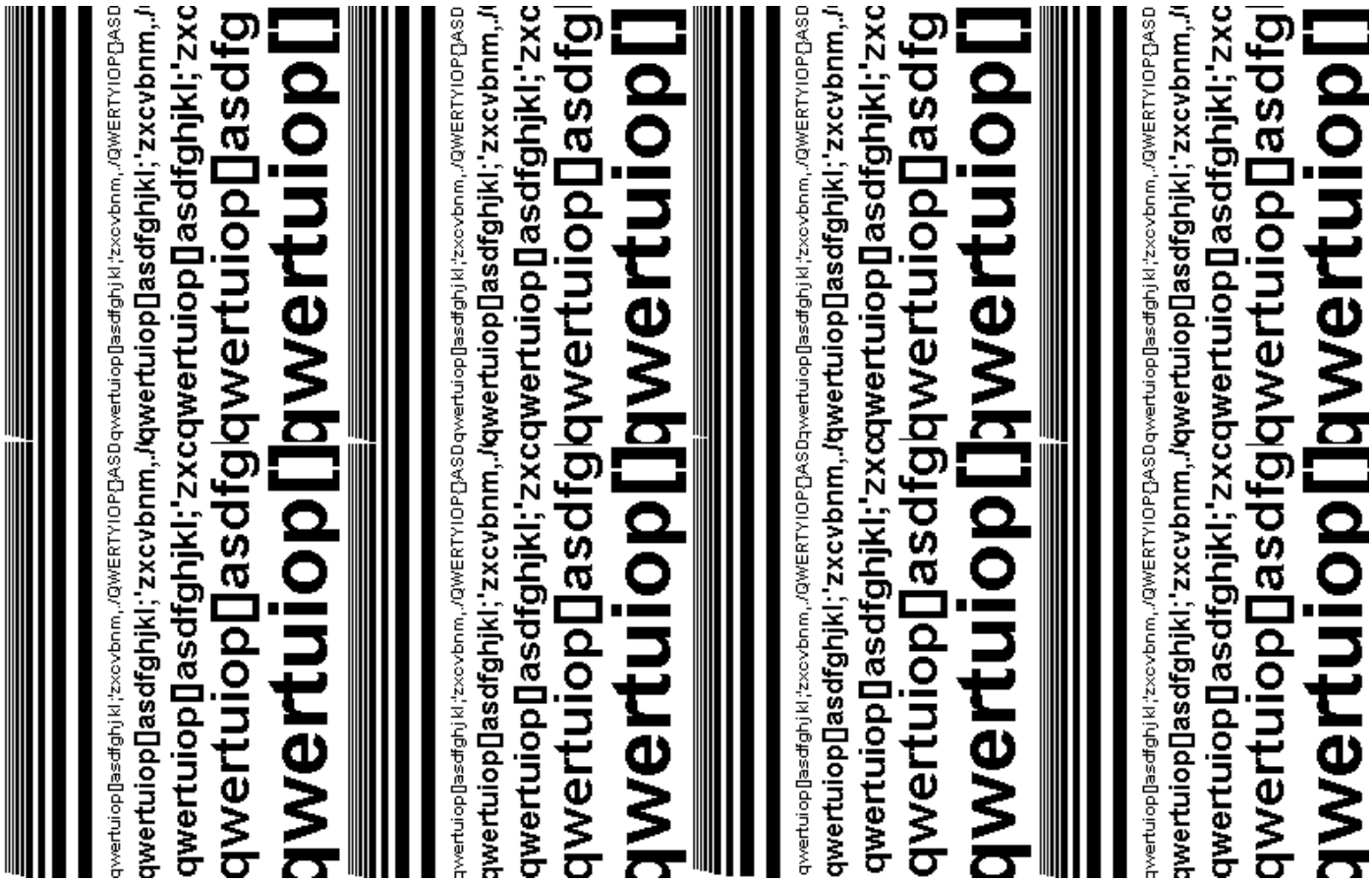

Test picture for checking accurate PCB-production.

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