DIRECTIONAL COUPLER CONSTRUCTION DETAILS

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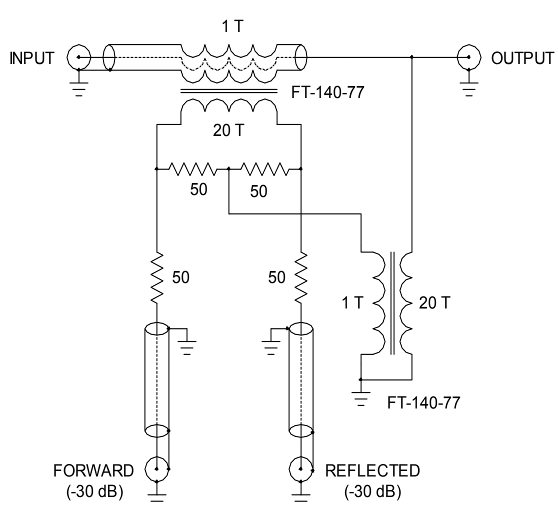
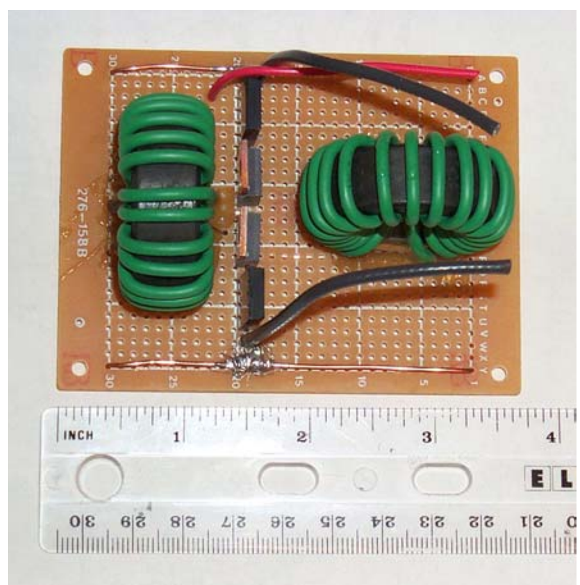
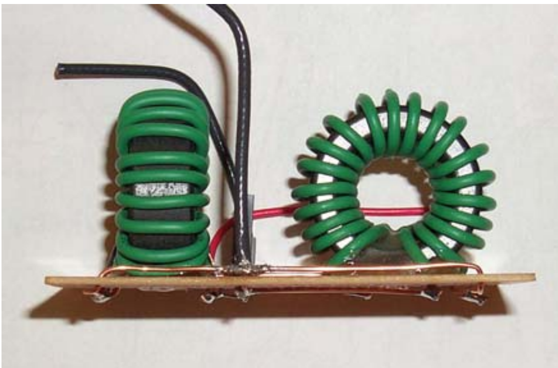
To fill the need for a dual directional coupler with optimal characteristics over the frequency span of the AM broadcast band – from 540 to 1700 kilohertz – and sufficient power handling capacity for use in a vector network analyzer system which employs power amplification to overcome the voltages that are typically induced on AM antenna towers, a design that employs two ferrite toroid transformers has been developed. The circuit provides a high degree of accuracy in the relationship of the forward and reflected samples over a wide range of load impedances. It also has minimal insertion effect, so that it may be used to measure operating impedances within directional antenna systems without significantly disturbing their parameters.



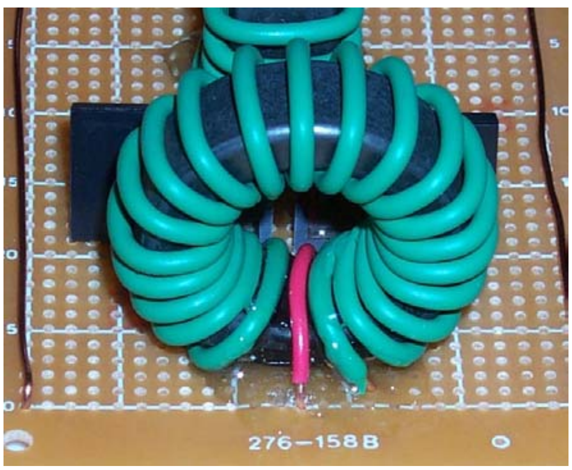
The toroidal cores are identical and each has 20 turns wound onto it. One is employed as a 20:1 ratio current transformer with a one-turn primary consisting of a Faraday shielded conductor to sample the current that passes to the output. The other is employed as a 20:1 voltage transformer with a secondary consisting of a single wire turn to sample the voltage that is across the output. The voltage sample establishes a reference voltage at the center point of a balanced circuit that employs two non-inductive precision resistors – each equal in value to the desired characteristic impedance of the directional coupler – with the sampled current passing through them in opposite directions relative to the center point, so that the voltages across them add to or subtract from the reference voltage depending on the direction of power flow. Voltages corresponding to the forward and reflected power are present on the two sides of the balanced circuit.



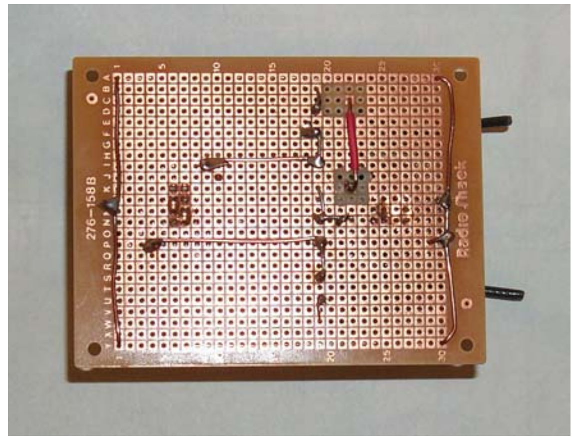
The prototypes have been built on Radio Shack part number 276-158B perforated circuit boards, which are 2.75 inches by 3.69 inches and have 750 holes for component mounting.



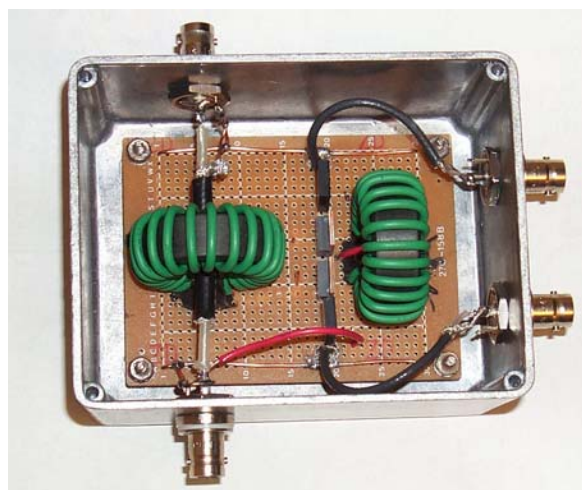
The toroids were wound with #18 AWG copper wire having 600V Insulation and were attached to the circuit boards with epoxy cement.



The wire that serves as the one-turn secondary of the voltage transformer (the one with smaller outside diameter insulation that passes through the open gap of the larger winding closest to the circuit board in the above photograph) should pass through the toroid by the most direct path possible rather than near its center. The hookup inductance of this winding must be minimized for the best high frequency performance.

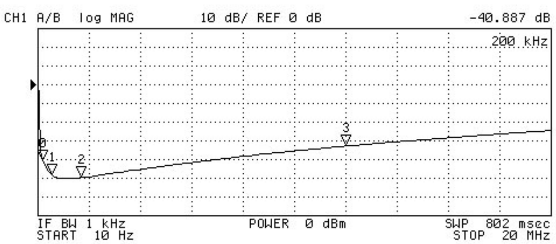


Point-to-point wiring - with #18 AWG copper wire - was used for all of the connections. A ground buss was run around the perimeter of the circuit board with the wire on the top along its long sides and on the bottom along its short sides. The foil pads were removed from the circuit board holes surrounding the ones through which the voltage transformer hookup wire passes for higher voltage isolation.



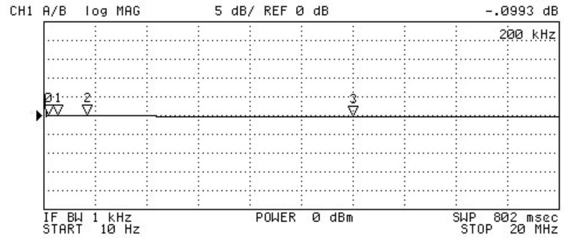
A short piece of RG-58 coaxial cable was used for the Faraday-shielded primary of the current transformer. Wire connections were made from the ground buss directly to the input and output connectors. Short pieces of RG-174 coaxial cable were used for hooking up the BNC connectors of the forward and reflected ports.

The circuit boards were mounted using stainless steel hardware and nylon spacers inside diecast aluminum enclosures.



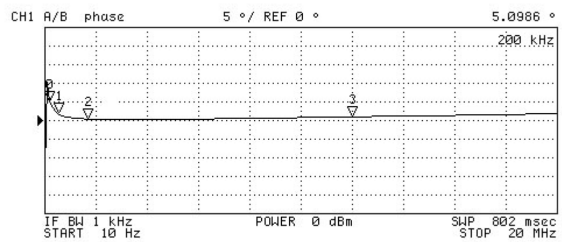
N	SWP PARAM	VAL
0	200 kHz	-40.887 dB
1	540 kHz	-48.061 dB
2	1.7 MHz	-49.645 dB
3	12 MHz	-32.799 dB

The measured directivity with the output terminated in a 50.0 ohm non-reactive load approaches 50 dB over the range of 540 to 1700 kilohertz, a value which would allow very accurate measurements even without the error correction that modern network analyzers employ. The directivity exceeds 30 dB, a value with which a modern network analyzer's built-in error correction can yield good results, over the range of 200 kilohertz to 12 megahertz.



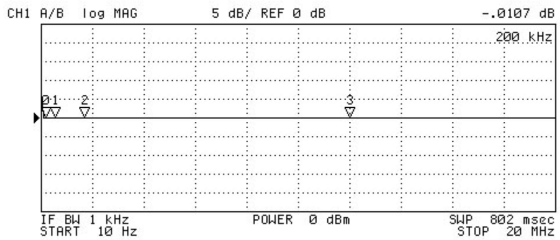
N	SWP PARAM	VAL
0	200 kHz	-.0993 dB
1	540 kHz	-.073 dB
2	1.7 MHz	-.1242 dB
3	12 MHz	-.272 dB

The forward and reflected samples with the output open-circuited, which should be of identical magnitude, differ by no more than 0.3 dB over the range of 200 kilohertz to 12 megahertz.



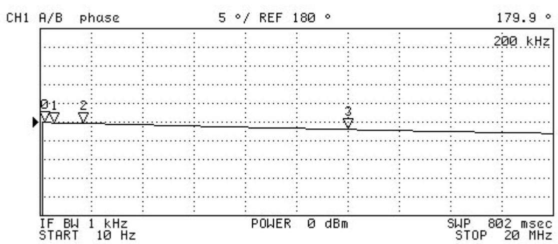
N	SWP PARAM	VAL
0	200 kHz	5.0986 °
1	540 kHz	1.765 °
2	1.7 MHz	425.76 m°
3	12 MHz	1.0047 °

The forward and reflected samples with the output open-circuited, which should be identical in phase, differ in phase by no more than 2 degrees within the AM band from 540 to 1700 kilohertz and remain within approximately 5 degrees over the range of 200 kilohertz to 12 megahertz.



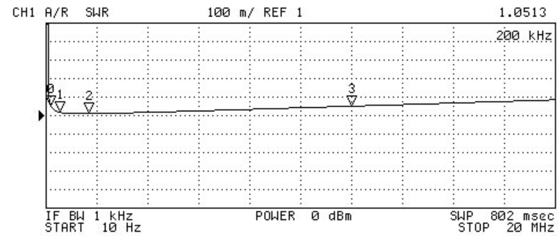
N	SWP PARAM	VAL
0	200 kHz	-.0107 dB
1	540 kHz	-.0262 dB
2	1.7 MHz	-.0435 dB
3	12 MHz	-.0513 dB

The forward and reflected samples with the output short-circuited, which should be of identical magnitude, differ by less than 0.1 dB over the range of 200 kilohertz to 12 megahertz.



N	SWP PARAM	VAL
0	200 kHz	179.9 °
1	540 kHz	179.81 °
2	1.7 MHz	179.66 °
3	12 MHz	178.02 °

The forward and reflected samples with the output short-circuited, which should be have a phase relationship of 180 degrees, differ from that value by less than 2 degrees over the range of 200 kilohertz to 12 megahertz.



N	SWP PARAM	VAL
0	200 kHz	1.0513
1	540 kHz	1.0199
2	1.7 MHz	1.0105
3	12 MHz	1.0508

The insertion VSWR, measured at the input port of the directional coupler with a 50.0 ohm standard connected to its output, is below 1.02:1 over the range of 540 to 1700 kilohertz and rises to approximately 1.05:1 at 200 kilohertz and 12 megahertz. It should be possible to utilize the directional coupler to measure transmission line operating impedances within an AM directional antenna system with minimal operating parameter disturbance, as long as the test leads used to make the external connections are short.

RATINGS

The directional coupler circuit has been tested and found to provide accurate impedance measurements with a power-amplified vector network analyzer system, after the standard open-short-terminated calibration procedure has been run, over the range of 200 kilohertz to 12 megahertz. The tests were run with test signal power ranging from less than a milliwatt to 100 watts with no significant indication of non-linearity. The component sizes and insulation voltage ratings of the conductors used in constructing the prototype directional couplers suggest that they should be able to withstand a power level of at least 500 watts, unmodulated, into a matched load. The circuit has not been tested for measurement accuracy at this design power level, which was chosen to make the circuit durable enough for measuring towers with tens of volts induced across their bases from nearby stations without suffering damage.

PARTS LIST

Resistors (4) - 50.0 Ohm, 1%, non-inductive power film, 2.25 Watt rating in free air. (Caddock MP-820 or equivalent)

Toroid Cores (2) – 1.40 by 0.50 inch with 0.90 inch hole diameter, Mix 77 (2000 permeability) ferrite. (Amidon F-140-77 or equivalent)

Enclosure – 4.68 by 3.68 by 2.06 inch diecast aluminum box. (Hammond Mfg. 1590C or equivalent)

HF VERSION

Another prototype has been developed for use with a network analyzer to make impedance measurements under power in the 3 to 30 megahertz range, using smaller 1.14 by 0.55 inch Mix 61 (125 permeability) toroid cores with 0.75 inch hole diameter (Amidon F-114A-61 or equivalent), mounted closer together on a smaller circuit board – to further reduce the series inductance between components - and placed within a smaller “minibox” type enclosure.