A BI-DIRECTIONAL INLINE WATTMETER

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GOOD ACCURACY FREQUENCY INDEPENDANT NO ADJUSTMENTS
LOW INSERTION LOSS WIDE POWER RANGE SIMPLE TO BUILD

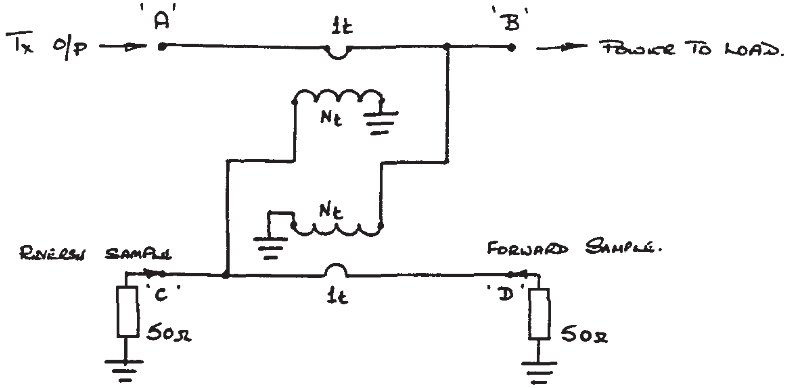
Asked to build a "transmitter VSWR meter", my fancy was taken by two variants of the Bruene circuit and I built one of each. The first uses a resistive potentiometer to sense the line voltage - found in the RSGB Manual. The second uses an autotransformer to sense the line voltage - found in an article by Ulrich Rohde in the US HAM RADIO magazine. Both proved to be less sensitive to stray than their ancestor, but I felt it might be possible to do better. The cause of their sensitivity to stray capacitance is the high impedance which the detectors present. Some calculations also showed that this high impedance was also limiting performance at the lower end of the range.

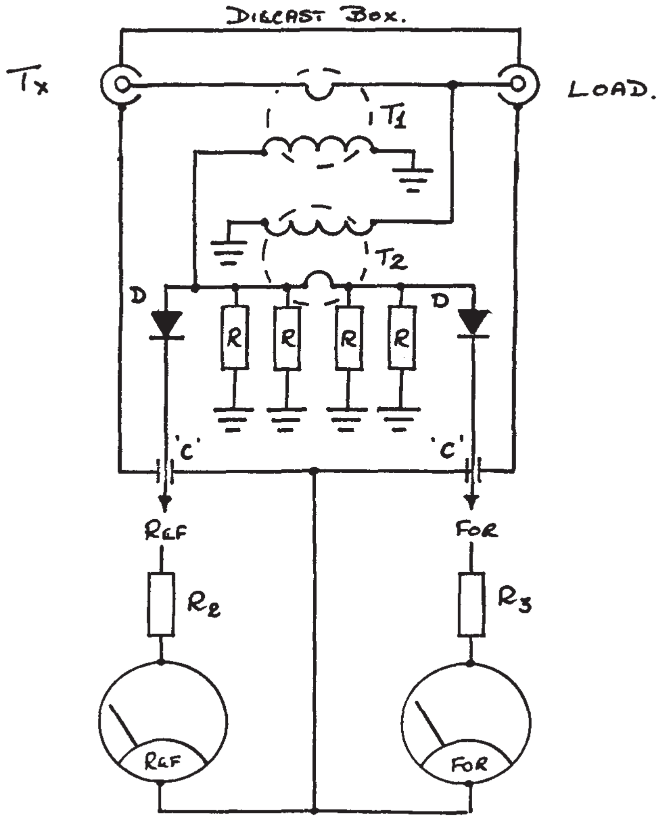
I started thinking of low impedance alternatives and suddenly remembered some professional work I had done on return loss bridges some 10 years ago. It happens that as circuit impedances are lowered, the bandwidth over which a transformer is usable increases, and I had designed a transformer based bridge which was usable from 10KHz to 40MHz with laboratory instrument class accuracy. This made me suspect that choosing a circuit with controlled, low impedances would be beneficial all round.

To experiment with transformer design I built a true 4-port Hybrid intended for 50 ohm use. A hybrid is a very simple circuit - just 2 transformers and 4 connectors - with some amazing properties. The connectors or ports are best thought of as two pairs. If a signal is passed in one connector and out of the other of a pair, into some unknown impedance load (say an antenna) then, if both of the other connectors are terminated in the intended system impedance (say 50 ohms) then the hybrid feeds a fraction of the power passing forwards through the first pair of connectors into one of the terminations. It feeds an equal fraction of the reverse power passing forwards through the first pair of connectors into one of the terminations. It feeds an equal fraction of the reverse power flow into the other termination. Hybrids can be designed to have different sampling fractions, usually quoted in dB, so a 20dB Hybrid diverts 1% of the flowing power to the appropriate terminated port. The really wild properties are that the circuit is symmetrical and the 2 pairs of ports can be reversed with no effect on function or performance, the signal can be fed through in the opposite direction in wbich case the forwards and reverse samples to the terminations are interchanged. Finally the hybrid itself contains nothing to set its operating impedance - the terminations on the sample ports do this. To convert a 50 ohm transformer hybrid into a 75 ohm one, just change from 50 to 75 ohm sample port terminations. If a large change of operating impedance is wanted, a transformer re-design may be needed to avoid some loss of bandwidth.

This circuit very nicely illustrates one of my favourite points. There is not necessarily any relation between number of components and "complexity". The operation of this circuit is extremely difficult understand, yet it only uses two components. Fortunately it is easy to build and easy to use.

Look at the symmetry of the circuit - due to a balancing effect of the transformers we can turn the circuit upside down, sway left for right, (or both) and it would still work the same.
Let us arbitrarity choose to feed our power into connector 'A' so our power passes through the transformers and 99% of it comes out of 'B' and goes to our load (the antenna) 1% comes out of connector 'D' and into its 50 ohm resistor.





METERS MAPLIN 5ØuA - 2 Needed
(not supplied in Kanga Kit)
R= 1ØØ ohms R2 = R3 (22K for 5W FSD. 56K for 2Øw FSD)

If the antenna does not present a perfect 50 ohm impedance, some power will be reflected and will pass backwards through the hybrid from B to A only 99% of the reflected power reaches 'A'.
1% is diverted to connector C and is dissipated in its 50 ohm resistor. In order to work, it is essential that C and D are terminated with good 50 resistors. The hybrid relies heavily on the match of ports 'C' and 'D'>

A prototype was built. The transformers were made with toroid cores of type S1 ferrite made by SEI (Salford Electrical instruments, Heywood, Lancs.) (Colour code: YELLOW) This ferrite is quoted for use to 2 MHz. Such statements usually refer to the range over which high - Q inductors can be made. Transformers are much less demanding and the usable frequency range is extended. The controlled impedance levels of the two transformers is very favourable and operation is good to about 50 MHz.

The prototype transformers had a single "primary" (with faraday screen) and a 12 t "Secondary".

With 12t, the coupling factor is - 21.584 dB. The prototype was measured at -21.59 ± 0.01 dB over 1.5 to 50 MHz. This flatness is excellent and the proximity to the calculated value for the first hybrid made (no adjustment or selection was done) shows the degree of confidence which can be placed in this type or circuit.

Plots of through path attenuation (<0.1dB 1.5 - 30 MHz) Coupling factor (21.59 ± 0.01 dB 1.5 - 30 MHz).

Directionality is the measurement of how well the hybrid can separate forwards and reverse samples. >23 dB directional power meter, we need only to add two termination resistors (50 ohms) and two diode detectors.

With a 21.6 dB (12:1 turns ratio) coupling factor the forwards termination dissipates 0.69% of the forwards power so two 100 ohm 1/2W resistors in parallel would be ideal for use with up to 150w continues carrier transmitters (580w PEP, unprocessed).

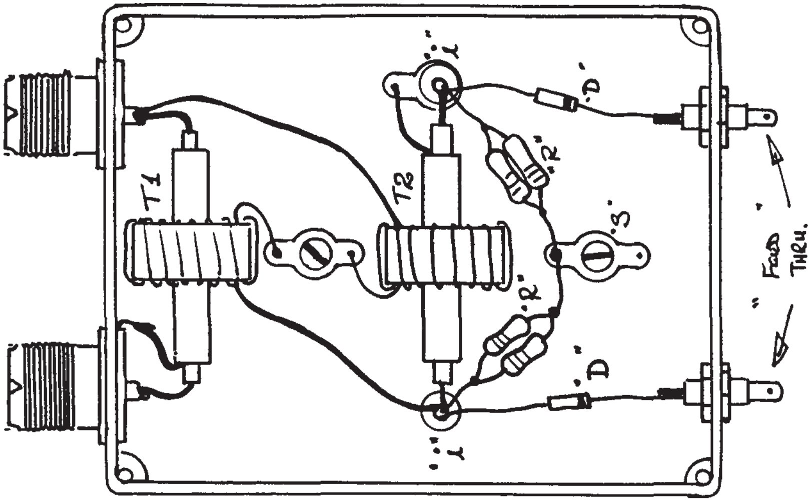
A good match gives zero reflected power. Interchanging the RF ports just causes the function of the two meters to be interchanged.

Two meters are really essential in this circuit, switching one meter merely detracts from the usefulness of the principle. Note that the principle of individual forwards and reflected power meters which do not have a VSWR scale not do Bird Thruline meters, not in one needed. If you know Forwards and Reflected power, you can esily convert to Return Loss (or VSWR) if you really wish.

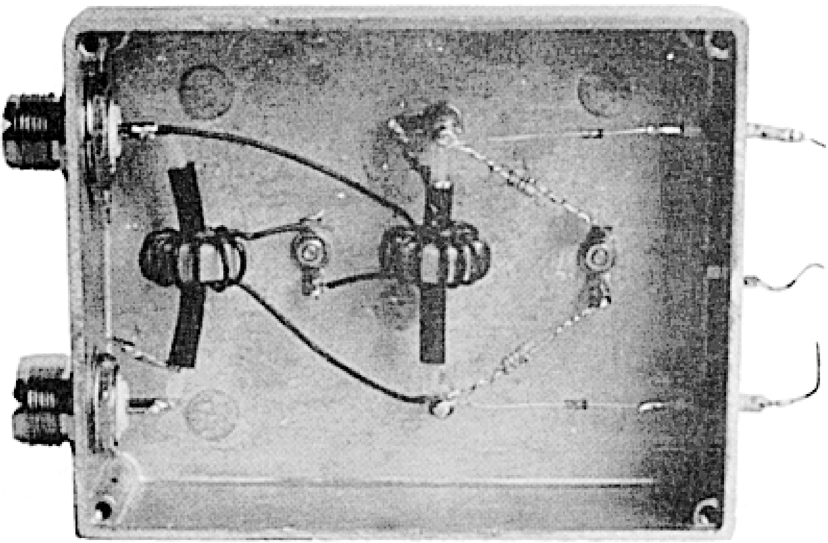
$$\text{Return Loss} = 10 \log_{10} \left(\frac{\text{Reflected Power}}{\text{Forward Power}} \right)$$

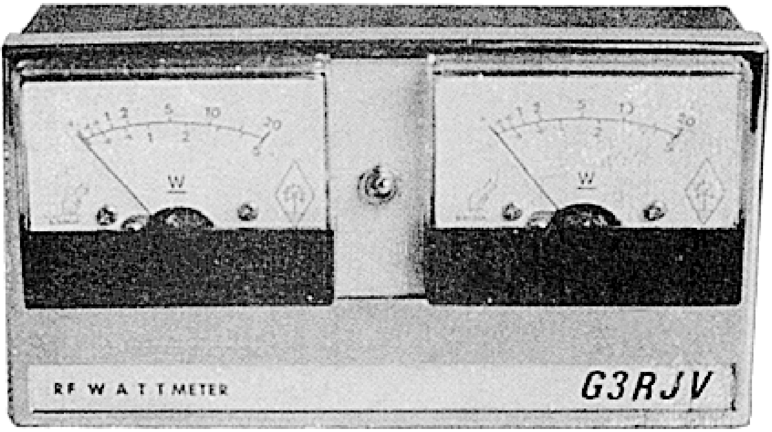
KANGA KIT VERSION
The protographs and diagrams refer to the Kanga Kit version of the Power Meter. This kit includes all that is shown in the "head" of the meter including the case, the special cores for T1/2 and all components. Two self adhesive scales are provided for the kit with two ranges: 5 watts and 20 watts FSD. This scale is designed for use with the MAPLIN 50uA Meter type FM98G. This meter is amongst the cheapest quality meters available. Several prototypes built with these meters showed excellent accuracy.

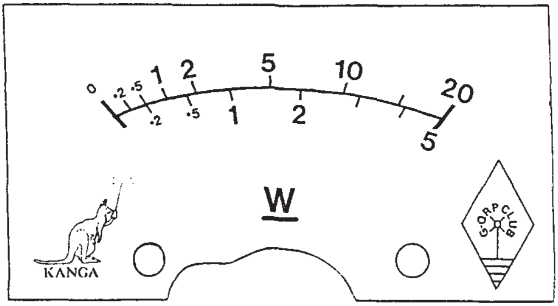
KIT PRICE TO CLUB MEMBERS (exc meters) £13.95 (post £1) from Kanga.



i = Standoff Insulators
T1/T2 = 12t. PVC covered wire - see text
Fit a tag on outside of case at S for Meter Negat
R = 100 ohm Low Inductive Resistors
D = Schottky Diodes
Feed Thru Capacitors - any value 1000 - 20,000pF







WATTMETER SCALES (5w & 20w FSD)
Stick-on Scales 2 supplied with kit These are for use with the stated values of R2 and R3 in the article. Alternative higher (up to about 200w) or lower full scale deflections can be had by changing R2 and R3.

U.QRP CLUB

EK3QRP on the EU/AS Border (Mt. Volchikha)

Left to Right:
RA9CCE - Sergej
RV9CIA - Boris
UW0LCN - Victor (seated)
RV3GM - Oleg (On Top)
UZ3GXX - Olga (xyl RV3GM)

The U QRP Club expedition in July 1989. 1590 QSOs in 10 days, all under 5w. 65 DXCC, All Continents, 135 Oblasts and many G QRP Club members inc. G8PG, G3YCC, OH9VL, I7CCF Most interesting QSO was WF9Y running 80mW on 20m. EK3QRP used a Homemade Transceiver with simple wire antennas on all bands.

Report by Oleg RV3GM