COMPLEX IMPEDANCE METER

This is a revised version of the talk and handouts which I presented to the Sydney VHF DX GROUP on Tuesday 20th June 2000.

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CONCEPT:
The concept of this complex impedance meter is due to Mr. Carl G. Lodstrom SM6MOM/W6 who worked at the Dow-Key Microwave Corp. at the time when RF Design journal called for entries to their First Annual RF Design contest. Lodstrom entered the contest with this idea and it was published in the Dec. 1986 issue of the magazine. A copy of Lodstrom's article is included herewith. The instrument described is my adaptation of Lodstrom's idea.

FUNCTION:
The instrument is particularly useful when setting up home brew antennas where the nature of the terminal impedance is uncertain. It will indicate whether the impedance is higher or lower than the desired 50 Ohm point and whether it is capacitive or inductive thus permitting informed adjustments to be made in order to "home in" on a good match. In this respect it is far more useful than a VSWR meter. Furthermore, it is an easy to build one that works because it does not rely on comparisons with imperfect resistors, capacitors or inductors as used in other impedance meters. A competent home brewer should have no difficulty making one for 23cm for example. However it does have limitations as listed later.

DESCRIPTION:
This instrument is simply a length of 50 Ohm transmission line with diode detectors placed at one eighth wave intervals along it so as to sample the voltage due to the standing wave caused by the termination which may be an unknown complex impedance.
The detector outputs are summed in pairs one quarter wavelength apart with the resultant voltage displayed on meters. One meter indicates the resistance of the load and the other the reactance. Instead of meters the voltages could be displayed on the X-Y axes of an oscilloscope. Lodstrom did this and pointed out that frequency sweeping a complex impedance would result in an oscilloscope display in the form of that seen on the Smith Chart.
A complete analysis of its operation is complex and has not been attempted by the author. Guy VK2KU has done something along these lines and written it up. His paper will be presented either as an accompaniment to this or as a separate item later.

METERS:
This instrument requires centre zero meters. The sensitivity is not important. The ones I used are 250uA FSD, 2000 Ohm. Centre-zero meters are not common although they can be bought through electronic parts supply houses. They are expensive and the home brewer may prefer to do what I did and convert old style normal zero meters to centre zero. This involves carefully taking the meter apart so as to obtain access to the spring or taut wire adjustment at the back of the armature. Turning this should enable you to set the needle to centre scale. Now that you have the meter apart you can make a new scale for it.

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METER SCALES:

The resistance scale on the resistance meter follows the same pattern as that on a VSWR meter or the resistance line on the Smith Chart.

% FS = 100C / 50 + C   Where C is the Cal. mark in ohms.

For a common meter which has a 90 degree full scale needle swing this becomes:

0	Ohms	=	0	degrees	
5	"	=	8.18	"	
10	"	=	15.00	"	
15	"	=	20.80	"	
25	"	=	30.00	"	
35	"	=	37.10	"	
50	"	=	45.00	"	= Centre scale.
75	"	=	54.00	"	
100	"	=	60.00	"	
150	"	=	67.50	"	
250	"	=	75.00	"	
500	"	=	81.80	"	
1000	"	=	85.70	"	

The reactance scale is the subject of some controversy. I assumed it would follow the same pattern as the change of impedance along an unmatched transmission line which is the same as that around the periphery of the Smith Chart. This is the common tangent curve. I calibrated my meter accordingly and checked it at five points using +/- 5% ceramic capacitors with very short leads connected directly to the unknown impedance socket. I could not resolve any error. This scale is thus:

Scale point for 'C' each side of centre = arctan C/50   Where C is the mark in ohms.

For the 90 degree needle swing meter this becomes:

0	Ohms	=	+/- 0	degrees	= centre scale.
5	"	=	+/- 5.7	"	
10	"	=	+/- 11.3	"	
15	"	=	+/- 16.7	"	
25	"	=	+/- 17.4	"	
35	"	=	+/- 35.0	"	
50	"	=	+/- 45.0	"	= end of scale.

It is not recommended that the scale be extended beyond 50 ohms. This would require a meter with lower sensitivity than the resistance meter adding unnecessary complexity. Furthermore Guy has suggested that the scale folds back on itself after 50 Ohms which would be confusing. His scale for zero to 50 Ohms does not follow that given above but does not differ by more than 10% at the greatest point of departure. See his paper for that scale and chose whichever you like. This will not affect the utility of the instrument one way or the other.

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ADJUSTMENTS

Preliminary: Set the balance pots to static centre with the aid of an Ohm meter.

1. With nothing connected to the unknown impedance socket, connect a source of RF power at the measurement frequency to the instrument via a variable attenuator. Note that this source of power can be the station transmitter with suitable attenuation or a purpose built test oscillator built into the meter. If the latter is your choice it is recommended that the oscillator have low output impedance so that its output remains steady as loads are changed. The amount of power required depends somewhat on the meters and diodes used. The example given requires less than 0.1 watts.
2. Adjust the attenuator so that the resistance meter reads full scale. The reactance meter may show a small deflection. Ignore it.
3. Connect the best 50 Ohm load you can find to the unknown impedance socket and adjust both balance pots for centre scale. i.e. 50 Ohms resistance and zero reactance.

The instrument is now ready for use. It may be checked by connecting a one eighth wavelength of 50 Ohm coax to the unknown impedance socket. Both meters should read 50 Ohms - capacitive in the case of the reactance meter. Or you can connect a lumped ceramic capacitor with an Xc between 0 and 50 Ohms at the measurement frequency to the unknown impedance socket via very short leads. The reactance meter should read the correct value. In this case the resistance meter will not read 50 ohms.
The demonstration instrument used 144.5 Mhz. At this frequency a standard value 22pF 5% capacitor has 50 Ohms reactance which is convenient! The resistance meter can be checked by connecting resistors other than 50 ohms (you have already done that) to the unknown impedance socket. They should read approximately the right value allowing that this is RF and they will have some reactance.

MEASUREMENTS

Simply connect the unknown impedance to the unknown impedance socket and read the meters. The value of resistance indicated will be close to correct provided that the reactance is low and the value of reactance indicated will be close to correct providing that the resistance is high. In cases where these provisos are not true, the indications will not be correct but the direction of movement of the meters will be correct. i.e If inductive reactance is indicated (which is common when setting up new antennas) the provision of a capacitive stub to tune out part of the inductance will bring the reactance meter closer to zero and the resistance indication closer to correct. Tuning the inductance out altogether will make the indicated resistance correct so that it may then be adjusted if necessary.
Note that the measurements are made at a measurement plane set by the length of L5. I think that the best place for this is at the measurement socket on the outside of the box.
If your antenna is not at this point the coax you use to connect it must be a multiple of half wavelengths long otherwise your measurements will be wrong. You may use the instrument to determine the length of this test cable.

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CONSTRUCTION TIPS: (see schematic at the end of this article)
The demonstration instrument is made for the two metre band. Note that the length of L5 determines the position of the measurement plane. Therefore the length must include the length of the connector if this point is to appear on the outside of the box.

The coax used for L1 through L5 can be any 50 ohm stuff you have but I recommend the use of UT141 which is semi-rigid, 3.6 mm OD, teflon insulated and solid inner stuff for 2m and 70cm. I would use microstrip line for instruments of 23cm or above.

When cutting the one eighth wavelength pieces the golden rule is "When in doubt, cut it short". Do not allow extra bits for what you may think may be part of the line length - you are almost invariably wrong. Of course you must consider the velocity factor of the cable. For UT141 this is 69.4%.

Keep the leads to the diodes and bypass capacitors as short as possible. The rule is: "If you can remove the component and use it again the leads are too long."

Both meters should have the same sensitivity.

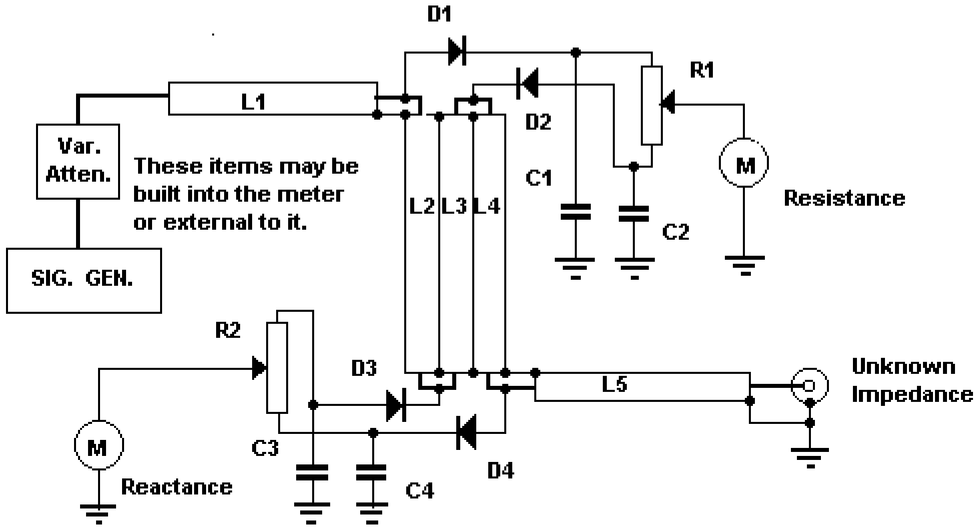
LIMITATIONS.

1. The instrument is narrow band. However it is useful over about 10% of centre frequency which should be more than adequate for amateur use.
2. It does not indicate the correct values unless the provisos given in the measurements paragraph are met. The readings indicated are not meaningless although we haven't yet worked out how to relate them to reality. It may be possible to do this and display understandable values with the aid of another meter perhaps. This is a project for the future which may result in an upgraded version of this instrument.

The schematic diagram is on the next page.

That's all from me for now,
Gordon McDonald VK2ZAB.

Minor editorial changes by Les Grant VK2KYJ, 16 July 2000.



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Components:

Lines L2 thru L5 are 50 ohms coax each 1/8 wavelength long. In the case of L5 this includes the length of the connector. L1 can be any convenient length.

R1 & R2 Linear pots. 22k, 50k or 100k both the same.

C1 thru C4. 1000pf to 4700pf Ceramic for 2M

D1 thru D4 Schottky 5082 - 2800 or similar.

Meters. Centre Zero. 50 to 500 microamps FSD.