APPLICATION NOTE 30

Date Revised
2/15/64

MEASUREMENT OF CABLE CHARACTERISTICS

Introduction

Measurements described in this Application Note are as follows:

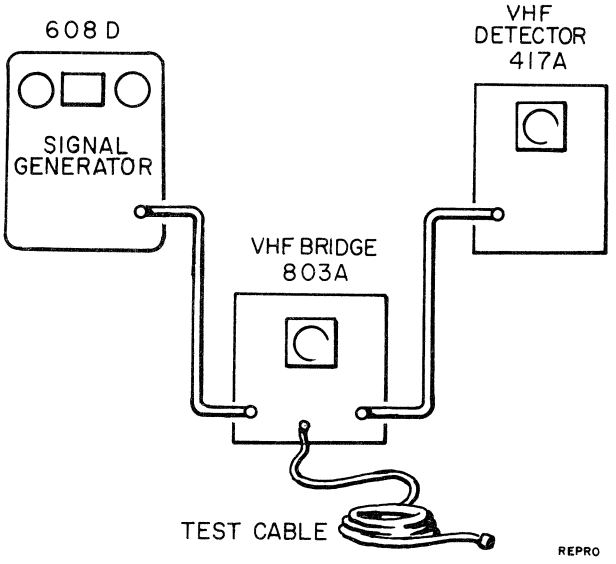
- Characteristic Impedance
- Standing Wave Ratio of Coaxial Cable Connectors
- Small Attenuation
- Large Attenuation

CHARACTERISTIC IMPEDANCE

Method: Open and short circuit

Block Diagram:

10 to 50 Mc



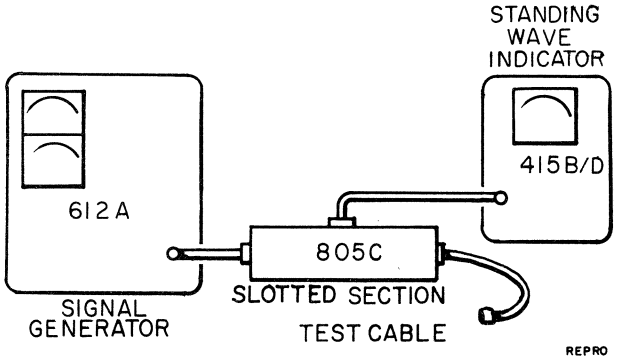
Measure direct input impedance of long cable length (250-500 ft) terminated in approximate Z_o. 803A is direct reading.[1]

50 to 500 Mc

Cut cable to approximately 1/8 wavelength. Measure open circuit and short circuit reactance.

Then $Z_o = \sqrt{X_{oc} \cdot X_{sc}}$

450 to 11,000 Mc



Cut cable to approximately 1/8 wavelength. Plot open circuit and short circuit impedance on Smith Chart. Convert to reactance.[2]

Then $Z_o = \sqrt{X_{oc} \cdot X_{sc}}$

Equipment List

Freq Range (Mc)	Signal Generator	Bridge or Slotted Line	Indicator
50-480	608C	803A	417A
450-1230	612A	805C	415B/D
800-2100	614A	805C	415B/D
800-2400	8614A	805C	415B/D
1800-4200	616B	805C	415B/D
1800-4500	8616A	805C	415B/D
3800-7600	618B	806B/809B/ 444A	415B/D
7000-11,000	620A	806B/809B/ 444A	415B/D

STANDING WAVE RATIO OF COAXIAL CABLE CONNECTORS

Method: Special techniques are required to measure small reflections (SWR) caused by coaxial cable connectors. Two schemes are available to make such measurements. Both require that the coaxial cable connectors be installed in a section of air line; special equipment is required to isolate the small reflections caused by the connectors.

[1] Cannot use $\sqrt{X_{oc}X_{sc}}$ because bridge may not balance for wide angle below 50 Mc.

[2] Do not use long cable length method because minimums and maximums cannot be located with low SWR.

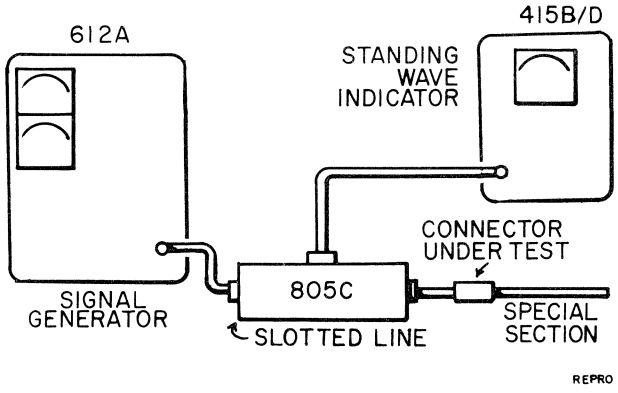
HEWLETT-PACKARD COMPANY
1501 PAGE MILL ROAD
PALO ALTO, CALIFORNIA, U.S.A.
CABLE: "HEWPACK" TEL. (415) 326-7000
54 ROUTE DES ACACIAS
GENEVA, SWITZERLAND
CABLE: "HEWPACKSA" TEL. (022) 42.81.50

PRINTED IN U.S.A.

Measurements on coaxial cable connectors which are made using the null shift method require construction of a coaxial line which can be extended in discrete sections. Careful measurement of the position of the null points in a slotted line will disclose data which can be interpreted in terms of the standing wave ratio of the connectors.

The perfect load method requires that the line containing the connectors be terminated in a moving coaxial load. Measurement of the SWR in the line, taken at various positions of the load, will enable the engineer to separate reflections of the load from those due to the connector and to thereby establish the standing wave ratio of the connectors. A rather complete description of both of these methods appears in: J.K. Hunton & W. B. Wholey, "The Perfect Load and the Null Shift - Aids in VSWR Measurements", Hewlett-Packard Journal, Vol. 3, No. 5 & 6.

Block Diagram:



Equipment List

Signal Generators	Frequency Range
612A	450 to 1230 Mc
614A	800 to 2100 Mc
8614A	800 to 2400 Mc
616B	1800 to 4200 Mc
8616A	1800 to 4500 Mc
618B	3800 to 7600 Mc
620A	7000 to 11,000 Mc
Slotted Lines	
805C	500 to 4000 Mc
806B with 809B Carriage, 444A Untuned Probe	3 to 12 Gc

Standing Wave Indicator: 415B/D

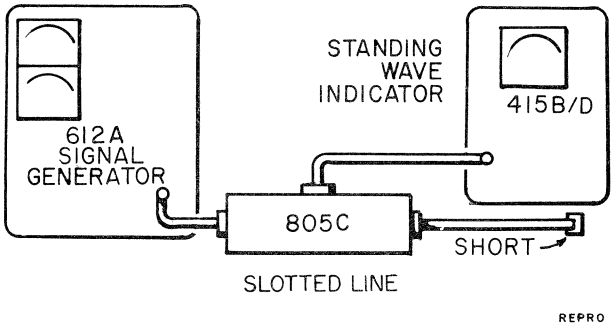
Special Equipment Required:

- Sliding Coaxial Load 906A
- Coaxial Line of Adjustable Length K04-999C
- Tapered Impedance Transformation with low residual SWR for matching connectors from the 50-ohm coaxial lines on the slotted line to connectors with a characteristic impedance other than 50 ohms.

SMALL ATTENUATION

Method: The attenuation is calculated by measuring the standing wave ratio of a shorted cable and substituting into a formula which relates the SWR, cable length, and the attenuation.

Block Diagram:



Procedure

a. The SWR of the shorted cable is measured in the 805C Slotted Line on the Model 415B/D Standing Wave Indicator.

b. The length of cable is measured.

Computation of Attenuation

1) For 50-ohm cables:

$$SWR = \frac{1}{\text{Tanh } \alpha L}$$

where αL is the one way attenuation

Note that if αL is much smaller than 1, Tanh αL is approximately αL and this formula reduces to

$$\alpha L = \frac{1}{SWR} \text{ Nepers or } \frac{8.686}{SWR} \text{ db}$$

2) For cables with a characteristic impedance other than 50 ohms, the impedance at the end of the slotted line is computed from standing wave ratio and the null shift when a short is applied at the end of the line. The impedance at the end of the slotted line can be computed using the usual formulas for measurement with a slotted line, or can be accomplished graphically using a Smith Chart with the noted SWR readings and shift of the minimum point when the line is shorted.

If we call the measured impedance Z_i, then $Z_i = Z_o \text{ Tanh } \alpha L$ where Z_o is the characteristic impedance of the line. αL is the one way attenuation.

$$\text{Then } e^{2\alpha L} = \frac{1 + Z_R}{1 - Z_R} \quad \text{where } Z_R = \frac{Z_i}{Z_o}$$

$$\alpha L = 1/2 \log_e \left| \frac{1 + Z_R}{1 - Z_R} \right|$$

Equipment List

Signal Generators	Frequency Range
612A	450 to 1230 Mc
614A	800 to 2100 Mc
8614A	800 to 2400 Mc
616B	1800 to 4200 Mc
8616A	1800 to 4500 Mc
618B	3800 to 7600 Mc
620A	7000 to 11,000 Mc
Slotted Lines	
805C	500 to 4000 Mc
806B with 809B Carriage, 444A Untuned Probe	3 to 12 Gc

Standing Wave Indicator: 415B/D

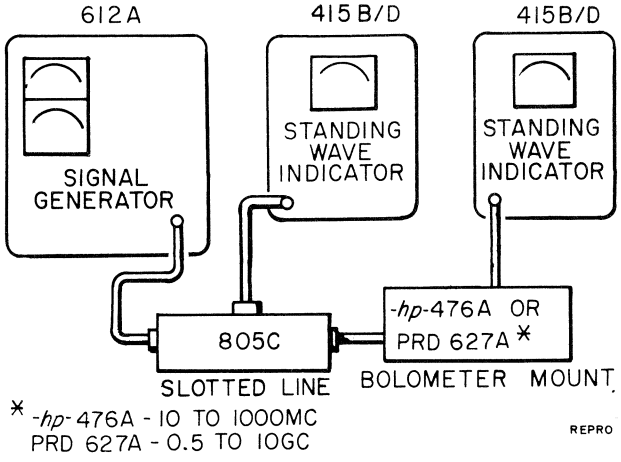
Reference:

Terman & Pettit, "Electronic Measurements", McGraw-Hill, 2nd edition, 1952, page 133.

LARGE ATTENUATION

Method: Insertion loss

Block Diagram



* -hp- 476A - 10 TO 1000MC
PRD 627A - 0.5 TO 10GC

Procedure

a. Check standing wave ratio in slotted line with 415B/D Standing Wave Indicator. The SWR should be below 1.10.

b. Set an initial convenient level on Standing Wave Indicator with signal generator output attenuator.

c. Insert cable under test between slotted line and bolometer mount.

d. Adjust attenuator on signal generator for the same level as in step "a" above.

e. For 50-ohm cables, the attenuation is the difference between signal generator attenuator settings.

For cables with impedances other than 50 ohms, the cable attenuation is the difference between signal attenuator settings less:

$$2 \left\{ 10 \log_{10} \left[1 - \left(\frac{Z_o - 50}{Z_o + 50} \right)^2 \right] \right\} \text{ db}$$

Equipment List

Freq Range (Mc)	Signal Generator	Bolometer	Slotted Line	Indicator
10 to 480	608C	476A	---	415B/D
450 to 1230	612A	476A/ PRD627A*	805C	415B/D
800 to 2100	614A	PRD627A	805C	415B/D
800 to 2400	8614A	PRD627A	805C	415B/D
1800 to 4200	616B	PRD627A	805C	415B/D
1800 to 4500	8616A	PRD627A	805C	415B/D
3800 to 7600	618B	PRD627A	806B/809B/ 444A	415B/D
7000 to 11,000	620A	PRD627A*	806B/809B/ 444A	415B/D

* PRD627A - 500 to 10,000 Mc

Additional Technical Information

For additional information about measuring transmission line and cable characteristics, refer to Application Note 62, "Time Domain Reflectometry".