A Variant in the Measurement of Two-Port Junctions*

GEORGES DESCHAMPS†

Summary—Projective constructions are described for deducing the iconocenter of a two-port junction from input reflection coefficient measurements taken with a short circuit placed in various positions in the output waveguide. The wavelength in the ouput line is deduced from a four-point measurement. If this wavelength is known in advance, a three-point measurement gives all the information needed to construct the iconocenter.

Introduction

A DETERMINATION of the scattering matrix of a two-port junction and methods for making impedance measurements through such a junction have been described.[1–3] They all make use of the iconocenter, *i.e.*, of the input reflection coefficient corresponding to a matched output waveguide.

When no matched load is conveniently available, the iconocenter can be deduced from the input reflection coefficient measured for two pairs of reactive loads, each pair corresponding to short circuits spaced a quarter-wave apart.

As pointed out by Wentworth and Barthel[4] restricting the displacements of the short circuit to quarter-wave steps or to some fraction of the wavelength can be very inconvenient when taking measurement on a single junction over a large band of frequencies: it means an adjustment of the short positions for each new frequency. The authors propose a solution based on arbitrary fixed location of the short circuits and give a construction of the iconocenter based on the intersection of two circles.

The present note describes solutions to the same problem which are based on projective constructions. They are simpler in that they do not require drawing of a larger number of circles. They also have the advantage of ***not requiring the knowledge of the wavelength*** in the output waveguide.

These constructions were in fact originally devised to determine the wavelength in Microstrip by indirect measurement. They would apply to any medium where it is not convenient to move the short circuit back and forth. In the measurement on Microstrip for instance, the line under test was successively cut to produce the reactive termination of variable phase, and there was no possibility to adjust this phase before knowing the wavelength.

The constructions will be described for reactive junctions but apply just as well to lossy junctions. They give the "crossover" point from which the iconocenter follows by the construction $\mathcal{B}$.[2]

Experiment and Constructions

The experimental procedure (Fig. 1) consists of placing the short circuit in 4 positions—1, 2, 3, 4—equispaced but not in any relation to the wavelength. The "images" or input reflection coefficients are plotted on the reflection chart as M_1', M_2', M_3', M_4', and fall on the circle Γ'. (Γ' coincides with the unit circle Γ when the junction is loss free.)

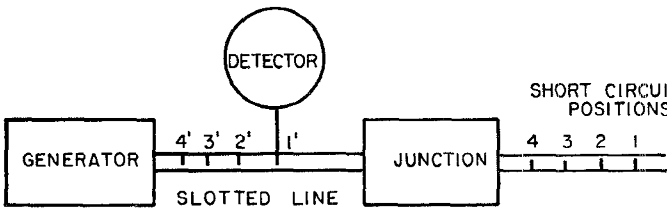

Fig. 1—Experimental setup.

Considering at first the 3 consecutive loads' positions 1, 2, and 3 in the output line, they are represented by M_1, M_2, M_3 on the unit circle Γ and the arc M_1M_2 equals the arc M_2M_3 [Fig. 2(a), next page]. The diameter of the circle Γ through the point M_2 therefore goes through the intersection T of the tangents to the circle Γ at the points M_1 and M_3. Using the projective representation of reflection coefficients[2] the image of this diameter [Fig. 2(b)] is therefore the line joining M_2' to the intersection T' of the tangents at points M_1' and M_3' to the circle Γ'. This is one locus for the image O' of O. Another straight line locus is deduced in the same manner from the points M_2', M_3', and M_4'. As shown in Fig. 3, O' is the intersection of the two lines, $T'M_2'$ and $U'M_3'$. The point O' image of O on the projective chart is called the cross-over point.[1–3] The iconocenter on the conformal (Smith) chart is related to it as described in these references.

There are many other versions of this projective construction. One that is particularly useful when the tangents to the circle Γ' do not intersect within the lim-

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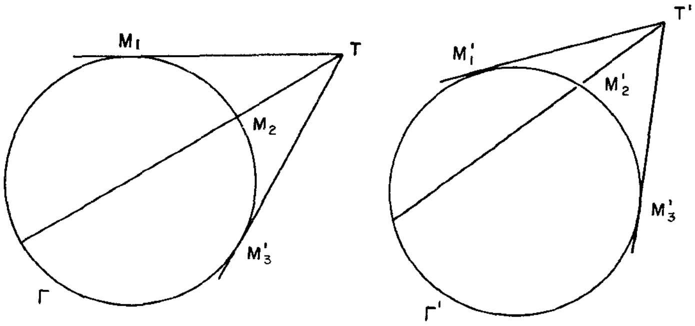
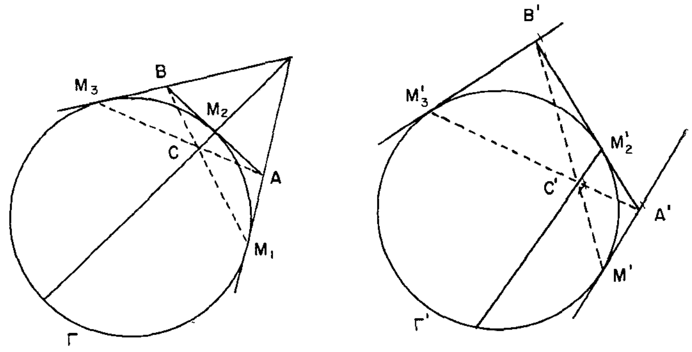
† Federal Telecommunication Labs, Nutley, N. J.

[1] G. A. Deschamps, "Determination of reflection coefficients and insertion loss of a waveguide junction," *J. Appl. Phys.*, vol. 24, pp. 1046–1050; August, 1953.
[2] G. A. Deschamps, "A Hyperbolic Protractor for Microwave Impedance Measurements and Other Purposes," Federal Telecommunication Labs, 1953.
[3] J. E. Storer, L. S. Sheingold, and S. Stein, "A simple graphical analysis of a two-port waveguide junction," Proc. IRE, vol. 41, pp. 1004–1013; August, 1953.
[4] F. L. Wentworth and D. R. Barthel, "A simplified calibration of two-port transmission line devices," IRE Trans., vol. MTT-4, pp. 173–175; July, 1956.



(a) (b)

Fig. 2—Projective construction of the image of a diameter.



(a) (b)

Fig. 4—Construction of the diameter image when the tangents at points M_1' and M_3' meet "out of bounds."

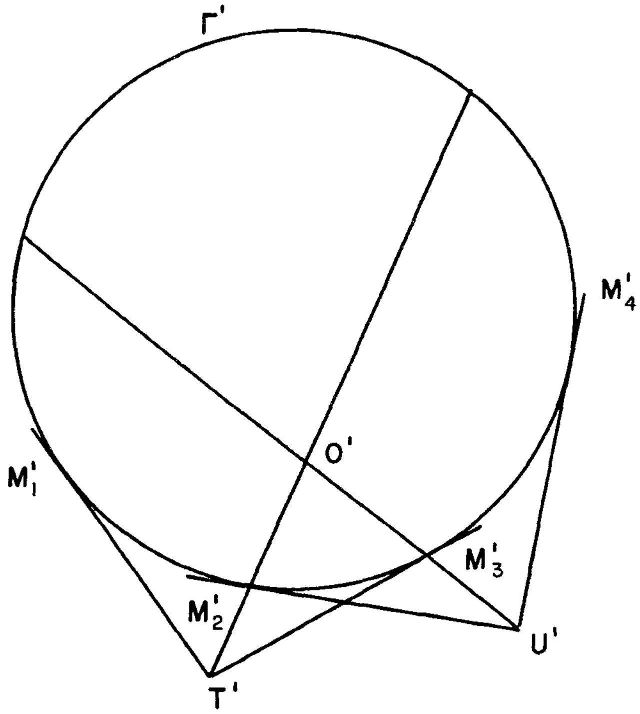
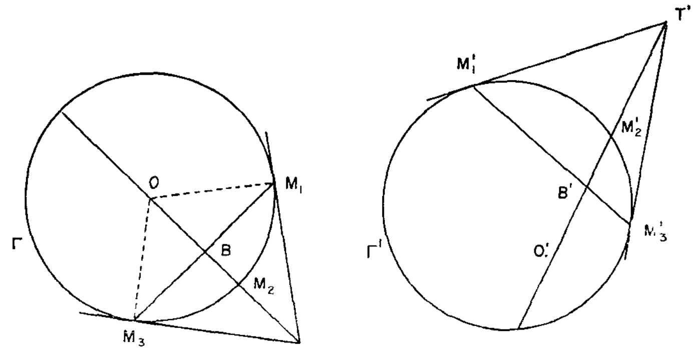


Fig. 3—Construction of the crossover point from the reflection coefficients for four equispaced loads (wavelength unknown).



(a) (b)

Fig. 5—Construction of the crossover point from a three-points measurement (wavelength known).

its of the page is shown in Fig. 4(b). The transform or image of the diameter is the line $M_2'C'$ where C' is the intersection of $M_1'B'$ and $M_3'A'$. This is justified by considering Fig. 4(a) before the transformation.

Once O' has been found, projection of M_1', M_2', M_3', M_4' through O' onto the circle Γ' will give the points M_1'', M_2'', M_3'', and M_4'' which are equispaced along this circle. The angle between two successive points (M_1'', M_2'') for instance, is the electrical angle corresponding to the displacement from 1 to 2; hence this gives a means of *finding the wavelength* in the output waveguide.

This determination of the wavelength resulted from measurement on four arbitrary equispaced loads. Conversely, if the wavelength is known in advance, the point O' may be determined from a three-point measurement. This is what is done in the construction of Wentworth and Barthel. A projective construction that leads to the same result quicker and without drawing circles is shown in Fig. 5. The diameter $M_2'T'$ is found as above and O' is located on that diameter by using the invariance of the hyperbolic distance.[2]

$$\langle O'B'\rangle = \langle OB\rangle.$$

Fig. 5(a) is drawn making use of the known electrical angle α between 1 and 2 or 2 and 3. The "distance" $\langle OB\rangle$ is measured on that figure with the hyperbolic protractor or it is computed by

$$\langle OB\rangle = 10 \log_{10} \frac{1+\cos\alpha}{1-\cos\alpha} = 20 \log_{10} \cot\frac{\alpha}{2}.$$

[In nepers the hyperbolic distance $\langle OB\rangle$ is the antigudermaniam of $(\pi/2)-\alpha$.] It is then used to lay out the distance $\langle O'B'\rangle$ on Fig. 5(b) by means of the hyperbolic protractor for instance.

There are many other projective constructions for three- or four-point measurements for completely arbitrary load positions that can be devised by anyone familiar with projective geometry. They are somewhat more laborious than those based on equispaced loads. The latter are therefore recommended since they are still compatible with measurements at variable frequency taken with fixed loads.

Another practical recommendation is to use more than four loads in order to increase the precision by some averaging. This also makes it possible to choose for the construction the points that show the best configuration; for instance, to avoid the use of points that are too close together.

Finally it should be noted that at a single frequency and when the wavelength is known, the quarter-wave spacing leads to a simpler construction. For variable frequency the measurements take less time when fixed short-circuit positions are used, but the interpretation is slightly complicated.

An obvious requirement when using this method is to have a good control on the frequency. In regions where the measured reflection coefficients vary rapidly with frequency, it may be advisable to go back to a measurement where the frequency is set and the short circuit moved.

Correspondence

WESCON Papers' Deadline Set for May 1

Authors wishing to present papers at the 1957 WESCON Convention to be held in San Francisco, Calif., on August 20–23 should send 100–200 word abstracts, together with complete texts or additional detailed summaries, to the Technical Program Chairman, D. A. Watkins, Stanford Electronics Laboratories, Stanford University, Stanford, Calif., for consideration by the Technical Program Committee. Authors will be notified whether or not their papers have been accepted by June 1.

For the first time this year, an IRE WESCON Convention Record will be published. It will include every paper presented at the 1957 WESCON and will be published immediately following the convention, for national distribution.

The IRE "Affiliate" Plan—A New Venture in Engineering Society Structure and Service

On January 4, 1957, the IRE Board of Directors arrived at a decision which may in time prove to be one of the most far-reaching in its 45-year history. On that date the Board adopted a plan which will enable non-IRE members whose main professional interests lie outside the sphere of IRE activities to become affiliated with certain of the IRE Professional Groups *without* first having to join the IRE itself.

This plan is aimed at those specialists in other fields of science and technology whose work touches upon our own electronics and communications field only in specialized areas. In effect, the IRE is extending the specialized services of its Professional Groups to every field of science and engineering.

An outstanding example of where these services are needed may be found in the case of the medical and biological sciences. At the present time some 1400 IRE members enjoy the privileges of membership in the Professional Group on Medical Electronics. And yet there are hundreds, perhaps thousands, of medical doctors, biologists, and others to whom the activities of this Group would be of interest and value. Both they and the Group would benefit from their participation. To require these persons, who have no interest in radio engineering, to join the IRE in order to join the Group is unreasonable, and probably futile as well. In fact, it was largely to provide an answer to this particular problem that the "Affiliate" Plan was first conceived, although it pertains to other fields as well, such as Computers, etc.

The "Affiliate" Plan is admittedly an experiment. So far as is known, no other society has ever tried a similar scheme. The Board of Directors feels strongly that the benefits afforded by the plan justify the risk that some persons who should join the IRE will instead become Affiliates. To minimize this risk, the plan has been carefully worked out along the following lines:

1) Participation in the Plan is at the option of each Professional Group. It is not expected that all Groups will adopt it; only those which feel it serves a need in their particular field.

2) Each Group interested in initiating the "Affiliate" Plan must submit to the Chairman of the Professional Groups Committee a list of accredited organizations which has been selected and approved by its Administrative Committee, for official approval by the IRE Executive Committee.

3) To be an Affiliate of a Professional Group, a person must belong to an accredited organization approved by that Group and the IRE Executive Committee. Moreover, he shall not have been an IRE member during the five years prior to his application. He may affiliate with more than one Group, provided the accredited organization to which he belongs is recognized by the Groups concerned.

4) The fee for Affiliates shall be the assessment fee of the Group, plus $4.50. The latter covers IRE subsidies to the Group, Professional Group overhead expenses borne by IRE Headquarters, and 50 cents which is to be rebated to IRE Sections for mailing and meeting costs.

5) An Affiliate will be entitled to receive the TRANSACTIONS of his Group and that part of the IRE NATIONAL CONVENTION RECORD pertaining to his Group. He will be eligible for a Group award, and may attend local or national meetings of the Group by payment of charges assessed Group members.

6) An Affiliate cannot serve in an elective office in the Group or Group Chapter, nor vote for candidates for these offices.

7) An Affiliate may hold an appointive office in the Group or Group Chapter.

8) An Affiliate may not receive any IRE benefits that are derived through IRE membership.

The "Affiliate" Plan is a bold and far-sighted venture; one that recognizes and provides for the rapidly spreading influence of electronics in every walk of scientific and technological life, and one that enables the IRE to further its aims as a professional engineering society—the advancement of radio engineering and related fields of engineering and science.

W. R. G. BAKER, *Chairman*
IRE Professional Groups Committee

Matching the Sides of a Parallel-Plate Region*

One of the simplest forms of electromagnetic wave is a TEM wave propagating between parallel conducting planes which extend laterally to infinity. It is perhaps not

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