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(54) **Stub for matching microstrip circuits.**

(57) Introduction of a minimum redundancy into a microstrip stub for microwave circuits allowing reversibility of adjustment, always operating in the same manner, that is by only removing or by only adding conductive material.

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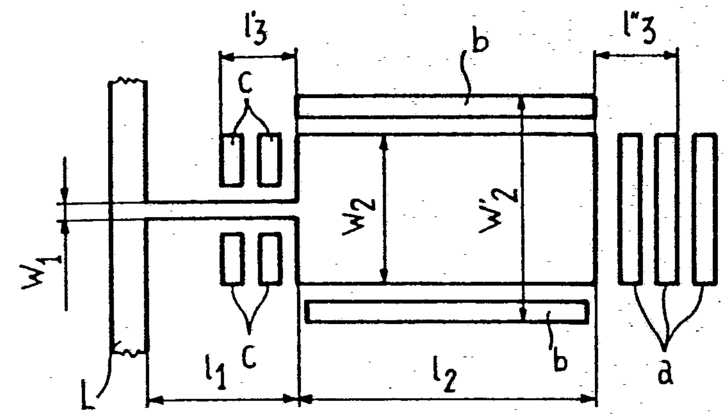


Fig.1

Stub for Matching Microstrip Circuits

The present invention relates to microwave circuits implemented by the so called microstrip technology and more particularly it concerns a stub for adjusting microstrip circuits.

One of the fields in which microstrip stubs can be used is the measurements of characteristics of the active components.

In fact to obtain the complete description of an active microwave device often it is not enough to effect on it just the measurement of the known diffusion parameters S, whose determination requires no adjustment.

In a number of cases it is necessary to connect at the input and at the output of the active device apparatuses able to introduce arbitrary variations in the impedances they present at the active device.

This is valid for instance in the case of noise-figure measurement at the variation in the input impedance or in case of optimum input-output impedances measurement to check the operation of a power device of non-linear type.

It would be of course preferable to effect such variations directly on the microstrip circuits containing the active device; but this is not convenient due to the typical irreversibility of microstrip matching devices.

In fact once the adjustment circuit has been modified, values prior to the adjustment cannot be recovered.

This difficulty is generally overcome by means of coaxial cable matching devices, provided that the transition from microstrip to coaxial-cable has taken place.

The inconvenient of the measurement method effected by means of coaxial matching devices resides in that a dismembering must be effected of component holder to measure the unknown impedance.

A further field in which microstrip stubs are generally used is the implementation of amplifiers, oscillators, mixers and others. For these devices direct adjustment is generally required of the matching networks, stubs enclosed, to compensate for the unavoidable parameter losses characterizing the active components (as commercially available) and to compensate for possible parassitic parameters of passive circuity.

Such adjustment is critical when the active components must be pushed beyond their threshold of power dissipation; certain load impedances,in fact where imprudently varied can give rise to a breaking of the active components to which they are connected. These dangers are often present in microstrip circuit embodiments as the known stubs, not being of reversible type, must be precalibrated with values in excess so as to allow the progressive approximation for reduction to required operation conditions.

In fact operating on a microstrip in the microwave range (bands X, K_u, etc.....), the usually method used for the circuit adjustment consists in removing the conductive material forming the microstrip; said removement is generally obtained through a laser beam, as the required precision in the adjustment is very high.

Otherwise many active power components require for conjugated matching a very low impedance, but they do not tolerate short circuit conditions.

Operating by laser removing technique, the main inconvenient is that of acting only by removing the material without any recovery, if the removement was too severe.

Obviuosly, the determination of the optimal condition can be obtained only by verifying worse performances beyond that condition.

That is why it is necessary to dispose of microstrip stubs of the reversible type, that is such as to allow easy scanning about the optimal condition.

Otherwise, in the superior microwave range, this reversibility cannot simply be obtained by adding other material after the removement of conductive material, since: above all the precision that could be achieved by adding further material would be poor, besides a much varied structure would result with respect to the original one with subsequent increased losses; finally such corrective material addition, necessarily requiring manual intervention, would not allow the automatic calibration process.

Operating always in microstrip in the lower microwave range (bands L, C) an adjustment method alternative to the one previously described of laser removement, is the one of providing while planning a certain number of areolae of conductive material at the edges of metalized strips of microstrip and duly connecting a certain number to the main strip to the attainment of the required conditions.

In this case due to the rather low frequencies these connections do not present serious problems.

From the literature it is not clear haw the reversibility can be obtained by utilizing said areolae method.

These and other problems of the present invention will be solved by a method devised to obtain the reversibility in stub microstrip adjustment modalities, that by introducing minimum redundancy in the stub topology allows this reversibility and optimal operation conditions to be obtained, operating always in the same direction, that is by the only removement of conductive material, for instance by means of laser, or by the only addition of conductive material by means of areolae method.

Another characteristic of the present invention resides in the fact that said slight added redundancy can be positevely utilized by interpreting the stubs realized in that way as elements of abroad band matching network or by sending a polarization through a choke connected to a short-cricuit section of the stub.

It is a particular object of the present invention a stub for the adjustement of microstrip circuits consisting of two cascaded lines, the second of which having a length comprised between 1/4 and 1/2 of the used wavelength.

These and other characteristics of the present invention will become clearer from the following description thereof of a particular embodiment of the same, taken by way of example and not in a limiting sense in connection with the annexed drawings in which.

- Fig. 1 is the most general version of a symmetrical reversible stub of the the type with metalization addition (method of areolae);
- Fig. 2 is the equivalent scheme of the stub depicted in Fig. 1;
- Fig. 3 is a particular asymmetrical case of the reversible symmetrical stub depicted in Fig. 1 in which there are just two series of aereolae, one for carrying out the lengthening and the other one the shortening;
- Fig. 4 is the complementary version of the stub of Fig. 3 as the shortenning and the lengthening operations are effected not by addition but by removement of conductive material;
- Fig. 5 is, analogously to Fig. 4, the complementary version of the stub of Fig. 1;
- Fig. 6 representes an intermediate adjusting method between the one depicted in Fig. 1 and that of Fig. 5.

Fig. 1 shows the typical form of a symmetrical reversible stub; it consists of two cascaded lines, the fist, connected to main line

L, has high characteristic impedance, and the second, left in open circuit, has low characteristic impedance.

References w_1, l_1 denote respectively the width and the length of the first line prior to adjustment; references w_2, l_2 denote respectively the analogous values of the second line prior to adjustement.

Reference l''_3 denotes the lengthening of the second line at the open end; reference l'_3 denotes the lengtheing of the second line at the end of the connection with the first line, that then corresponds also to a shortening of the first line.

Reference w'_2 denotes the widening of the microstrip relating to the second line.

References a, b, c denote some areolae placed in adwance while planning the microstrip in suitable number and size, to carry out the required adjustments.

In the equivalent circuit of Fig. 2 reference Y_0 denotes the characteristic admittance of the main line L of Fig. 1.

References Y_1, l_1 denote the characteristic admithance and the length of the first line w_1, l_1 prior to adjustement; references Y_2, l_2 denote the analogous values of the second line w_2, l_2 always before adjustement.

In Fig. 3 references L, l_1, l_2, l'_3, l''_3, w_1, w_2 denote the same values as in Fig. 1.

Reference a denotes the same anolae as in Fig. 1; reference c' denotes the areolae that correspond, in the asymmetric version, to those denoted by a in the symmetric version of Fig. 1.

In Fig. 4 references L, l_1, l_2, w_1, w_2 denote the same values as in Fig. 1.

References l'_4, l''_4 denote areas of conductive material that can be partially or totally removed to realize the wonted adjustments.

In Fig. 5 the originary configuration of the microstrip is the same as in Fig. 1; the dotted lines denoted by d, e, f, represent areas of conductive material that can be removed while adjusting.

References l_1, l_2, w_1, w_2 denote the same values as in in Fig. 1.

In Fig. 6 references a, b, c denote the same areolae as in Fig. 1, but this time during the planning they have not been plotted outside of (as they have in Fig. 1), but they have been plotted inside the original configuration of the microstrip and have been subsequently covered with conductive material (dotted zone) easy to remove, for instance by a sharpened stylus. References l_1, l_2, w_1, w_2 denote the same values as in Fig. 1.

With reference to the annexed drawings, the function will be now described of the adjusting method of the stub, object of the invention.

With reference to the generalized version with metalizing addition in Fig. 1, the initial equivalent circuit is the one of Fig. 2.

By adding to a second line (l_2, w_2) areolae of type a, length l_2 is increased by an entity that, for instance, in case the two first areolae of type a were incorporated is equal to l''_3, i. e. passing from length l_2, to $l_2 + l''_3$.

By adding to second line (l_2, w_2) some areolae of type b, width w_2 increases; in case for instance both areolae b represented in Fig. 1 were incorporated one would pass from width w_2 to w'_2: characteristic admittance Y_2 of Fig. 2 increases accordingly.

By adding to the second line (l_2, w_2) areolae of type c, length l_2 increases, for instance in the case depicted in Fig. 1, by l'_3 and l_1 diminishes by the same value.

Let us consider now the known expression of the input admittance B, normalized with respect to Y_0

$$jB = j\left(\frac{Y_1}{Y_0}\right)\frac{\tan g\,\beta l_1 + \left(\frac{Y_2}{Y_1}\right)\tan g\,\beta l_2}{1 - \left(\frac{Y_2}{Y_1}\right)\tan g\,\beta l_1 \cdot \tan g\,\beta l_2} \qquad (1)$$

in which β is the phase constant, considered as equal, in the two microstrip lines. The expression (1) is for instance reported in "Foundation for Microwave Engineering" by R. Collin, Chapter 5. New York Mc Graw - Hill, 1966.

From (1) it derives that when l_2 increases (for instance by l''_3), B increses; but if tang $\beta l_2 < 0$ (that is if $\frac{\lambda}{4} < l_2 < \frac{\lambda}{2}$, being λ the microstrip wavelength), B decreases when Y_2 increases or when l_2 increases, for instance by l'_3 (and correspondingly l_1 decreases by the same value).

Consequently, while connecting areolae of type a there is an increase in electric length (as it happens in case of a single line stub), incorporating areolae of type a and b everything works as if the stub electric length decreased.

The same reversibility property is present if the removement operation of conductive material was taken into consideration instead of area conglobation.

In fact, by considering (1) again it can be seen from Fig. 5 that when the conductive material is removed from side d (that is when l_2 decreases) B decreases, but if tang $\beta l_2 < 0$ B increases when Y_2 decreases (removement of material from side e) or l_2 decreases to the advantag of l_1 (removement of material from side f).

As a consequence a single transmission line in open circuit used in shunt (that is a stub) can be converted into a reversible line (that is into a line that can be lengthened or shortened by the same method of adjustment no matter whether it consists of the addition or of the removement of conductive material) if said line is replaced by the cascaded connection of two different transmission lines, the second of which has a length l_2 comprised between $\lambda/4$ and $\lambda/2$ ($\lambda/4 < l_2 < \lambda/2$); the length l_1 of the first line is free and depends on the initial value positive or negative of B that is to be realized.

The operating modalities of the stub of Fig. 6 are strictly analogous to those of Fig. 5; however in this case while designing the microstrip, initial areolae a, b, c, are to be prearranged (as in Fig. 1) that must be covered with conductive material of the soft type that is easy to remove.

It has to be specified that the diagrams with areolae (Fig. 1, 3 and 6) are particularly suitable for not too high frequencies (<3 GHz); while diagrams of Figures 1, 4 and 5 are necessary in case of high frequencies (>3 GHz).

The methodology described here is based on the replacement of a single line by a cascade of two lines and then by the introduction of a redundancy.

Such redundancy can be usefully employed also, to send the polarization to active devices or to match loads on wide band.

It is enough to note that the second line (l_2, w_2) is a line with low characteristic impedance and has a length comprised between $\lambda/4$ and $\lambda/2$. Therefore an intermediate position exists (corresponding to $\lambda/4$) in which a short circuit at radio frequency is present with broad band due to the low impedance characteristic of the line.

This short circuit section can be utilized to insert a choke to send polarization voltage.

What we claim is:

1. Stub for matching microstrip circuits, characterized in that it consists of two cascaded lines, the second (l_2, w_2) of which has a length comprised between 1/4 and 1/2 of the used wavelength.

2. Stub according to claim 1 characterized in that the only addition of conductive material at suitable points of said sub causes both the increase and the decrease of the admittance (B) characteristic of the line; said increase or said decrease in the admittance exclusively depending on the point of the stub to which the conductive material is added.

3. Stub as in claim 1, characterized in that the only removement of conductive material at suitable points of said stub causes both the increase and the decrease in the characteristic admittance (B) of the line; said increase or said decrease in the admittance depending only on the point of the stub from which the conductive material is removed.

4. Transmission stub for matching microstrip circuits, the whole as described in the text and depicted in the annexed drawings.

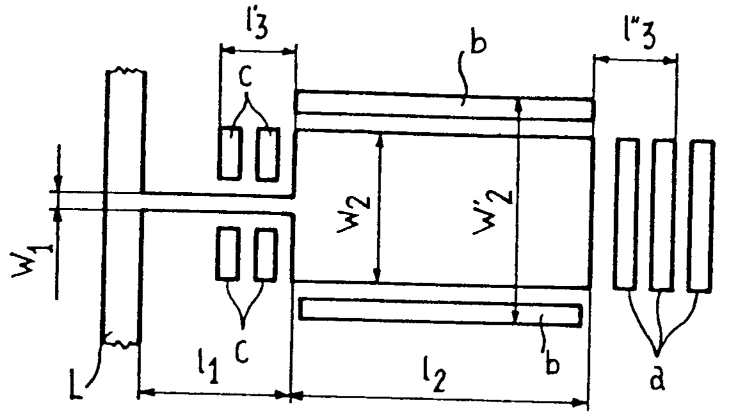
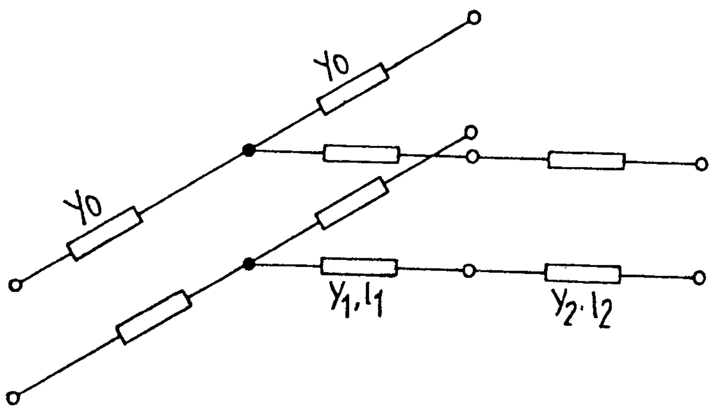


Fig. 1

Fig. 2



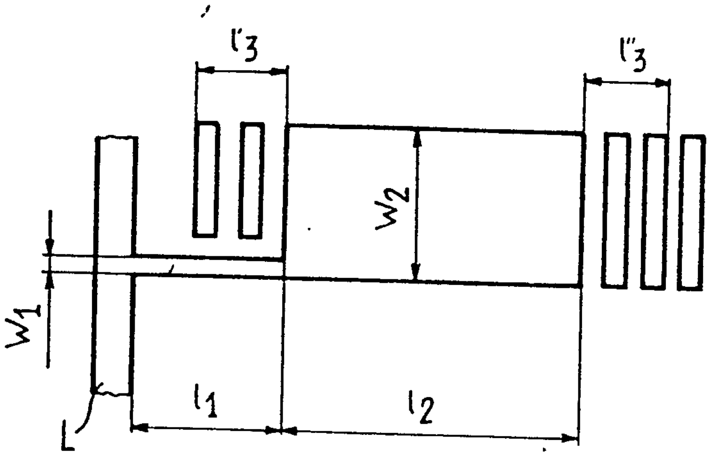
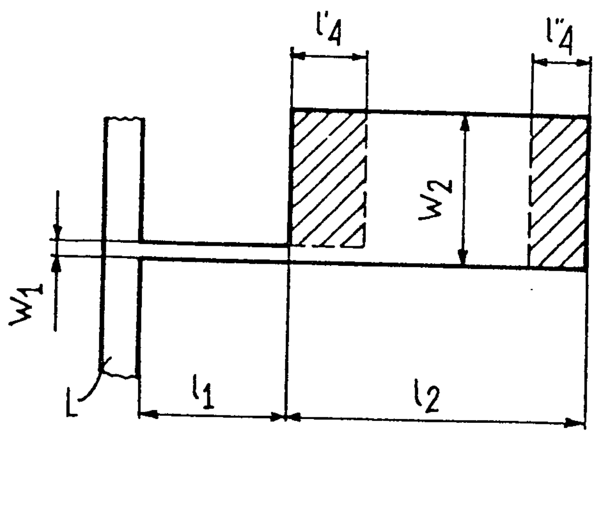


Fig. 3

Fig. 4



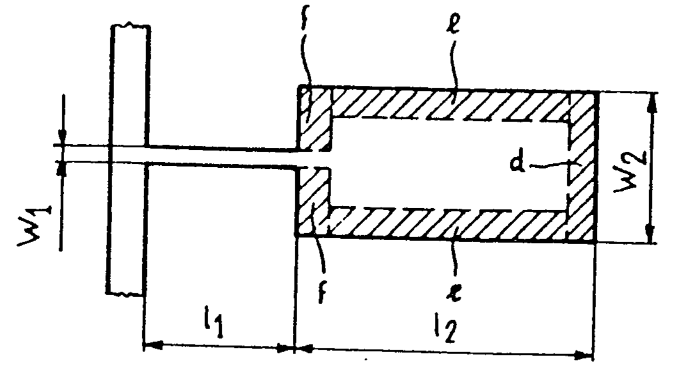


Fig. 5

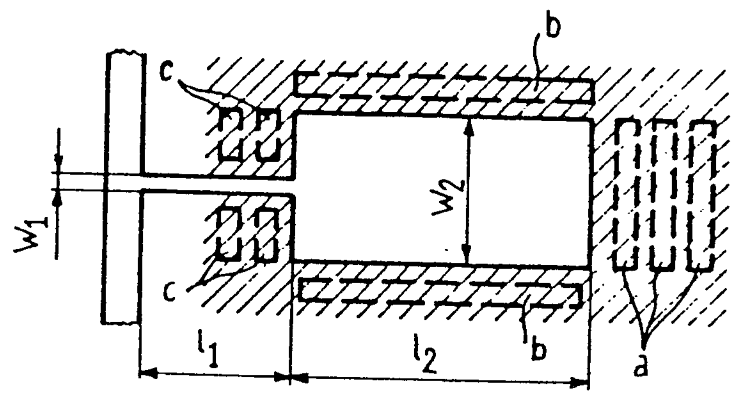


Fig. 6

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EUROPEAN SEARCH REPORT

Application number EP 80 10 6677

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	US - A - 4 070 639 (J.T. NEMIT et al.) * column 4, line 47 to column 5, line 9; figures 1A and 3 * --	1,4
	FR - A - 1 212 982 (C.S.F.) * the whole document * --	1,4
	US - A - 4 105 959 (V. STACHEJKO) * column 3, lines 39 to 49; figure 1 * --	1,4
	US - A - 3 417 352 (M.J. WALLER) * abstract; column 3, lines 15 to 29; figures 1 and 4 * --	1,4
	US - A - 2 819 452 (M. ARDITI et al.) * the whole document * --	2-4
	US - A - 2 820 206 (M. ARDITI et al.) * column 4, lines 4 to 28; figures 7,8 and 9 * --	2-4
	US - A - 4 157 517 (T.F. KNEISEL et al.) * the whole document * -- ./.	2-4

CLASSIFICATION OF THE APPLICATION (Int. Cl.3)

H 01 P 5/02
7/08

TECHNICAL FIELDS SEARCHED (Int. Cl.3)

H 01 P 1/20
5/00
7/08

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
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T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	11-02-1981	LAUGEL

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EUROPEAN SEARCH REPORT

Application number
EP 80 10 6677

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	DE - A - 2 310 371 (LICENTIA PATENT-VERWALTUNGS-GmbH) * the whole document * --	1-4	
A	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-19, no. 7, July 1971 NEW YORK (US) M. CAULTON et al.:"Status of Lumped Elements in Microwave Integrated Circuits - Present and Future" pages 588 to 599 * the whole document * -------	1-4	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)