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(54) Band-pass speedy tunable filter of the combline-type.

(57) Band-pass speedy tunable filter (20) of the combline type, the electrical circuit of which is provided with semiconductor devices (D_1,D_2,D_3) so connected that: the junction capacity of each one is liable to controllable variation depending on the controlled variation of the applied reverse tension (V_c) of polarization; a corresponding variableness of the center frequency of the passing band is thereby possible; the speedy tuning of such a filter (20) depends on the very short delay (in the range of nanoseconds) of the occurred variation of the junction capacity in respect to the moment that the reverse tension (V_c) was applied. The improvement due to the insertion of suitable semiconductor devices (D_1,D_2,D_3) - either of the MESFET-, or HEMT-, or VARACTOR-type - in the equivalent circuit of this band-pass filter (20), as well as the improvement relating to the use of a control rheophore (25) acting on the by-pass inductances (LB1,LB2,LB3) of the circuit make as desired said junction capacity dependent on the applied reverse tension (V_c;) and the center frequency is thereby liable to controllable variation whose values increase with that applied reverse tension (V_c).

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BAND-PASS SPEEDY TUNABLE FILTER OF THE COMBLLNE-TYPE

The present invention relates to improvements in combline-type filters. More specially, it relates to improvements in band-pass speedy tunable filter of the combline-type the electrical circuit of which is provided with semiconductor devices so connected that: the junction capacity of each one is liable to controllable variation dependent on the controlled variation of the applied reverse tension of polarization; a corresponding variableness of the center frequency of the passing band is thereby possible; a band-pass speedy tunable filter of the combline type is consequently realized.

The improvement due to the insertion of semiconductor devices - either of the MESFET-, or HEMT-, or VARACTOR-type - in the equivalent circuit of this band-pass filter, as well as the improvement concerning the use of a control rheophore acting on the by-pass inductances provided in such circuit to make, as desired, said junction capacity dependent on the applied reverse tension of polarization. The center frequency f_o of this combline-type filter is thereby liable to variation controlled by the operator, whose values increase with the applied reverse tension.

By looking through the technical literature of prior art, wide explanations may be found as regards the features and possible practical application of microwave filters wherein the resonators are arranged as the teeths of a comb, and the band-pass response is obtained through the selective coupling of the component resonators, each one having its own inductance LR and its own capacity CR. The resonance condition is expressed by the value f_o of the center frequency according to the well known formula:

$$f_o = \frac{1}{2\pi} \frac{1}{\sqrt{LR(C+CR)}}$$

wherein the capacity C expresses the so-called head capacity of the filter.

When a signal with a frequency near the resonance is supplied to the filter input, the resulting output signal is only lightly attenuated; when, on the contrary, the frequency of the input signal is very different in respect to the resonance frequency, the output signal results greatly attenuated, so that the combline-type filter assumes the characteristic of a "band-pass filter".

Further referring to the combline-type filter of the prior art, it is obvious to deduce that in accordance with above formula, the center frequency f_o, namely the resonance frequency, depends substantially on the cited head capacity C, with an inverse proportionalty. It is also important to note that the center frequency f_o assumes generally a fixed value depending on the selected fixed value of the head capacity C.

As a particular consequence of these features pertaining to the combline-type filters of the prior art, the structure of these latter is used for mechanical-type filter, as evidenced, for example, in a McGraw-Hill, Inc. publication (1964) with relations of Matthaei, Young, Jones concerning microwave filters. Such a structure is more seldom exploited to realize filters on micro-strip printed circuit (see Arpad D.Vincze-IEEE Transactions on Microwave Theory and Techniques - Vol. MTT-22, No.12, Dec.1974) because the constructive semplifica tion of the printed circuit finds, in opposition, less favourable performances of the circuit in respect to the former case.

As premised, the main object of the invention is to overcome the disadvantageous fixed value of the center frequency f_o depending on the fixed value of the so-called head capacity C of a combline-type filter according to the prior art. The fundamental structure of a combline-type filter for microwave according to the prior art is now replaced with an innovated structure in accordance with the present invention. A set of resonators is provided in a combline arrangement, one end of each resonator being earthed, for example, by a single metal strap for all resonators, while the opposite end of each one is connected to a respective semiconductor device and then in series to a controllable capacity C, which is liable to variation by controlling the reverse (direct) tension of polarization. A source of direct current is provided in order for supplying a reverse tension V_c in the range of 0 to plus/minus 20 V as desired and controlled by the operator,through suitable control rheophore and connecting wires.

On the ground of experiments it was found that semiconductor devices of the MESFET-, HEMT-, or VARACTOR-type are actually suitable to allow a controllable variation of the junction capacity C dependent on the applied reverse tension of polarization. In substance, the junction capacity C decreases when the applied reverse tension increases; and on the ground of/the recalled formula cited above, the decrease of the junc-tion capacity C causes a corresponding increase of the center frequency f_o.

The important innovating features of the invention are evidenced by graphic representations of the frequeny on Cartesian co-ordinates, generally referred to the applied reverse tebsion of polarization, or the attenuation of the input signal (ordinate), and the corresponding response frequency (abscissa). The increasing values of the center frequency f_o dependent on the sequentially controlled application of the reverse tension lie generally along a line parallel to the abscissa.

A remarkable characteristic to be point out for this combline-type filter concerns the time necessary to notice a desired variation of the junction capacity after the reverse tension has been controlled. In effect, there is a very short delay from the moment such a reverse tension has been controlled by the operator, to cause the variation of the junction capacity, such a delay being in the range of nanoseconds. Because of its remarkable features the combline-type filter according to the invention is, in effect, a band-pass speedy tunable filter which may overcome the difficulties arising from the prior art in this field. Furthermore the invention solves the very important problem of how to design practically a band-pass speedy tunable filter of the combline-type wherein the "head capacity" does not have a fixed value and therefore a single center frequency f_o, this latter being, on the contrary, liable to variation, which depends on the reverse tension of polarization controlled by the operator.

In order to give the skilled in the art the possibility of better interpreting the innovating features of a combline-type filter in accordance with the invention and value the advantages deriving from the practical use of same, a preferred embodiment is described hereafter by referring to the accompanying drawings. Some considerations about a conventional combline-type filter of the prior art are also premised to render easier the comprehension and deductions.

In the drawings:

Fig. 1 is a schematic top view of a band-pass filter assumed with Three resonators in a combline arrangement;

Fig.2 is a schematic top view of a band-pass speedy tunable filter according to a preferred embodiment as example of the invention;

Fig.3 is a lower side view of the filter shown in Fig.2;

Fig.4 is a sectional view along the line 4-4 of Fig.2;

Fig.5 is a schematic operating wiring diagram suitable for the band-pass filter of Fig.2;

Fig.6 shows a set of diagrams " reverse tension - response frequency " of a speedy tunable filter according to the invention;

Fig.7 is an assembled outer view of a structure containing a speedy tunable filter, provided with input- and output-connectors;

Fig.8 is a schematic top view of the structure of Fig.7, the cover of which was partially removed to show, in turn, a schematic view of a band-pass speedy tunable filter of Fig.7 housed therewithin;

Fig.9 is a block system wherein a filter according to the invention is shown in connection to a pulse generator and oscilators;

Fig.10 shows a set of graphic representations " reverse tension-response frequency" in Cartesian co-ordinates, with values of attenuation (ordinate) in dB and response frequency (abscissa) in GHz;

Figs.11a to 11c - show schematically some possible earthing connections of the filter resonators according to the invention;

Fig.12 is an example of inductive connection of the filter resonators through straight conductor line;

Fig.13 is an example of inductive connection through a bent conductor line;

Fig.14 is an example of capacitive connection;

Fig.15 is an example of a transformer-type connection.

A fundamental structure of conventional combline-type filter according to the prior art is shown in fig.1 and shortly described hereafter so that the comparison may be made with a combline-type filter in accordance with this invention. In fig.1 a set of three resonators are supposed in a combline arrangement within the cavity of a metal container 11. By looking through fig.1, it may be noted that the resonators have their lower ends solidly connected to the inner wall of the cavity and thereby earthed, while the opposite end of ech one is connected to the facing inner wall of the cavity through an intermediate capacity C inserted therebetween. Each resonator has his own inductance LR1, LR2, LR3, respectively as well as coupling inductance LaE and LaU are provided in connection to the power input^E and power output U, respectively. In fig.1 the intermediate capacity is indicated by the reference character C and symbolizes the head capacity of such a combline-type filter. Because of this structure of prior art, the center frequency f_o of the passing band is expressed by the well known formula reported hereabove, which gives the resonance condition and is bound to the inductance LR and capacty CR of the resonators, and depends on the head capacty, or tuning capacity C of the filter. It is thereby possible to deduce that a fixed value of f_o corresponds to a fixed value of head capacity C of the passing band, as it may be seen by looking through graphic representation "attenuation (ordinate) -response frequency (abscissa)".

A typical example of structure of a microwave filter in accordance with the innovating features of the invention, namely the controllable variation of the head capacity and thereby the corresponding variation of the center frequency of the filter, is shown schematically in figs. 2 to 4, wherein such a filter is indicated with the reference number 20. It was assumed that this filter is provided with a set of three resonators R1, R2, R3 in combline arrangement upon an insulating bed 24 placed on the flat upper surface of a base 21 of a rectangular metal support member 21-22 having a thick square shaped projecting part 22 which according to figs.2 to 4 forms the left longitudinal side of the support member. Insulating bed 24 is leaning against the inner face of the projecting part 22, and the surfaces of these two elements 22, 24 are substantially complanar in order for being covered by a suitable metal strap 23 which covers and solidly connects therebetween either one end of the resonators and the corresponding part of the metal projecting element 22. In this manner such ends of the resonators are earthed.

By comparing the structure shown in figs. 2 to 4 with that shown in fig.1, a remarkable difference is evidenced therebetween.

By looking throughthe top view of fig.2 it may be seen that a semiconductor device, generally indicated with the reference character D, is connected to each free end of the resonators R1, R2, R3 to exploit the variability of the junction capacity of such a device, the variation being controlled by the opera tor, by suitably regulating the applied reverse tension on which the junction capacity depends.

Semiconductor devices suitable to satisfy the controllable variation of such junction capacity were found of the MESFET-, or HEMT-, or VARACTOR-type, specifically suitable to realize variations of capacity through variations of reverse tension, and formed on gallium arsenide (GaAs).

Each selected semiconductor device is inserted between the resonator R and the by-pass capacity CB according to the electrical circuit 50, schematically shown in fig.5. By looking through the circuit 50 it may be seen that the resonators R1, R2, R3 have been assumed as having: its own inductance LR1, LR2, LR3, respectively; input coupling inductance LaE and output coupling inductance LaU; and inductance M between the adjacent resonators. By-pass inductances LB1, LB2, LB3 are provided between respective semiconductor devices D1, D2, D3 and the positive of a direct voltage source V_c to be controlled by the operator for realizing as desired the variation of the reverse tension of polarization on which is depending the variation of the junction capacity of the semiconductor devices.

In this connection,it may be important to recall the remarkable characteristic pointed out hereabove: the desired variation of the junction capacity happens with a very short delay from the moment that such reverse tension has been controlled by the operator, such very short delay being in the range of nanoseconds.

Turning now to the schematic views of figs.2 to 4, it may further be useful to a skilled in the art to list as follows its compo nents and the connections of same:

R1, R2, R3 are the resonators placed upon the upper surface of an insulating bed 24 in a combline arrangement, this latter being, in turn, placed on the flat base 21 of the main metal support member 21-22;

LaE, LaU are the input- and output-inductances, respectively, of the resonators, these coupling inductances being assumed along straight lines;

D1, D2, D3 are semiconductor devices of the MESFET-, or HEMT-, or VARACTOR-type;

CB1, CB2, CB3 are by-pass capacities;

25 indicates the control rheophore to vary the reverse tension of polarization to be applied for varying as desired the junction capacty, and after all the center frequency f_o of the filter at the resonance condition;

LB1, LB2, LB3 are by-pass inductances;

23 is the covering metal strap to earth one end of all resonators through the solidly connected projecting part of the metal support member;

V_c indicates the direct reverse tension of polarization liable to variation controlled by the operator.

As recalled hereabove, tension V_c is liable to controllable variation in the range 0 to plus/minus 20 V, to obtain corresponding variations of the junction capacity of the semiconductor devices D1, D2, D3. As premised, corresponding variations of the center frequency f_o depend on the cited formula. It will be understood that any increase of the reverse tension (i.e. a tension which does not cause a current flux) causes a decrease of the junction capacity of the semiconductor device; and when such a junction capacity decreases, an increase of the center frequency f_o is provided.

In fig.6 generic graphic representations are shown on rectangular Cartesian co-ordinates which are referred to tha attenuation A (ordinate) of an input signal corresponding to controlled different values of the applied reverse tension, and to the frequency f (abscissa). Three decreasing values of the applied reverse tension were assumed, indicated by the reference characters V_1, V_2, V_3, respectively, the peak of each diagram corresponding to the respective center frequency f_o.

Similar graphic representations are shown in fig.10 of the accompanying drawings and more clearly referred to a band-pass speedy tunable filter of the combline-type in accordance with the invention. It was assumed that four decreasing values of V_c were selected and controlled by the operator in the range of attenuation A (ordinate) from 60 dB to 0 dB. Four corresponding increasing values of the center frequency f_o (abscissa) are shown in the range from 6 GHz to 18 GHz.

In fig.8 an example is schematically shown of the possible assembling of a combline-type filter according to this invention in a box structure 34 with a closing cover 33, two facing walls of the box being provided with coaxial input- and output- connectors 31, 32, respectively to carry out the necessary connections to those instruments of a system 40 wherein the important function of such a band-pass speedy tunable filter of the combline-type is an advantageous application.

An example of such a system 40 is shown in fig.9 wherein a filter according to the invention is connected to some representative blocks of following instruments:

41 - pulse generator
42 - oscillator
43 - detector
44 - oscilloscope

As premised and sometime recalled, a selection of semiconductor devices D1, D2, D3 is possible, the MESFET-, or HEMT-, or VARACTOR-type being preferred on the ground of experiments in this connection. The selection may be extended to other components of the filter in accordance with this invention, and figs.11 to 15 evidence, among other possible modifications, some possibilities concerning: the earthing connection of the resonators; the inductive as well as the capacitive coupling. By looking through the schematic representations of figs.11 to 15 the skilled in the art may thereby see following examples of realization:

An earthing connection of the resonators provided:

- through a single metal strap for all resonator (fig.11a)
- trough a single metal strap for each resonator (fig.11b)
- by through-holes (fig.11c)

When a single metal strap is provided to earth all resonators, the inductive coupling of these latter with filter-input E and filter-output U may be performed :

- through a straight connecting line between input E and the first resonator, as well as between the third resonator and the filter output U, this third resonator being, in this example of embodiment, the last resonator of the filter (fig.12);
- through a bent connecting line (fig.13) while the capacitive coupling may be provided:
- as indicated by the character c between the filter input E and the first resonator, and between the last resonator and the filter output U (fig.14);
- a "transformer" coupling may also be provided (fig.15).

It is however important to take in a right consideration the distances a and b signed on to above figs.12 to 14, namely from the point at which the connection to the resonator is made up to each one of the two opposite other ends of this latter.

It is furthermore to point out that the embodiment of the invention as specified is an example only of the innovating features of same and does not have any limitative purpose. Modifications and changes eventually suggested by the skilled in the art are from now on to be included in the claims when actually pertaining to the ground principles of the present invention.

Claims

1. A band-pass speedy tunable filter of the combline-type (20) provided with a set of resonators (R1, R2, R3...) arranged as the teeth of a comb, in the equivalent circuit of which a respective semiconductor device (D1, D2, D3...) is included for each resonator in order to realize a junction capacity liable to controllable variation depending on the reverse tension of polarizarion controlled by the operator and realize consequently a center frequency (f_o) of the passing band the values of which increase relative to the applied reverse tension,

characterized in that it comprises:

- a main metal support member (21-22) which is made of a rectangular flat base (21) to assemble thereon the filter components and has a longitudinal projecting side (22) of a square shape to define the placement of a rectangular insulating bed (24) thereon, the upper surfaces of said projecting side (22) and said insulating bed (24) being substantially coplanar;
- a set of resonators (R1, R2, R3...) transversally leaning upon the upper surface of said insulating bed (24) in a combline arrangement, one end of each resonator being extended up to the projecting side of said main metal support member (21-22); each resonator having its own inductance (LR1, LR2, LR3...), and said set of resonators being coupled to the filter input (E) and filter output (U) through an inductance (LaE-LaU), respectively, an inductance (M) being further provided between the adjacent resonators;
- a metal strap (23) which covers and solidly connects to each other either said projecting side (22) of the main metal support member and the near ends of all resonators, so that these latter may, in turn, be earthed;
- a set of semiconductor devices (D1, D2, D3...), each one preferably placed along the line of respective resonator and electrically connected to the corresponding free end of these latter;
- a set of by-pass capacities (CB1, CB2, CB3...) each one preferably placed along the line of re-

spective resonator and semiconductor device in a series connection to these latter;
- a source of direct current to supply a controllable reverse tension (V_c) by a control rheophore (25) and through the by-pass inductances (LB1, LB2, LB3...) which are connected thereto.

2. A band-pass speedy tunable filter as claimed in claim 1
characterized in that
said semiconductor devices are of the MESFET type upon gallium arsenide (GaAs).

3. A band-pass speedy tunable filter as claimed in claim 1
characterized in that
said semiconductor devices are of the HEMT type, on (GaAs).

4. A band-pass speedy tunable filter as claimed in claim 1
characterized in that
said semiconductor devices are of the VARACTOR type on (GaAs).

5. A band-pass speedy tunable filter as claimed in claims 1 to 4
characterized in that
the control rheophore (25) allows generally tha attenuation of signal depending on the applied reverse tension of polarization in tha range from 0 to plus/minus 20 V, and thereby the corresponding variations of the junction capacity and response center frequancy (f_o) of the filter.

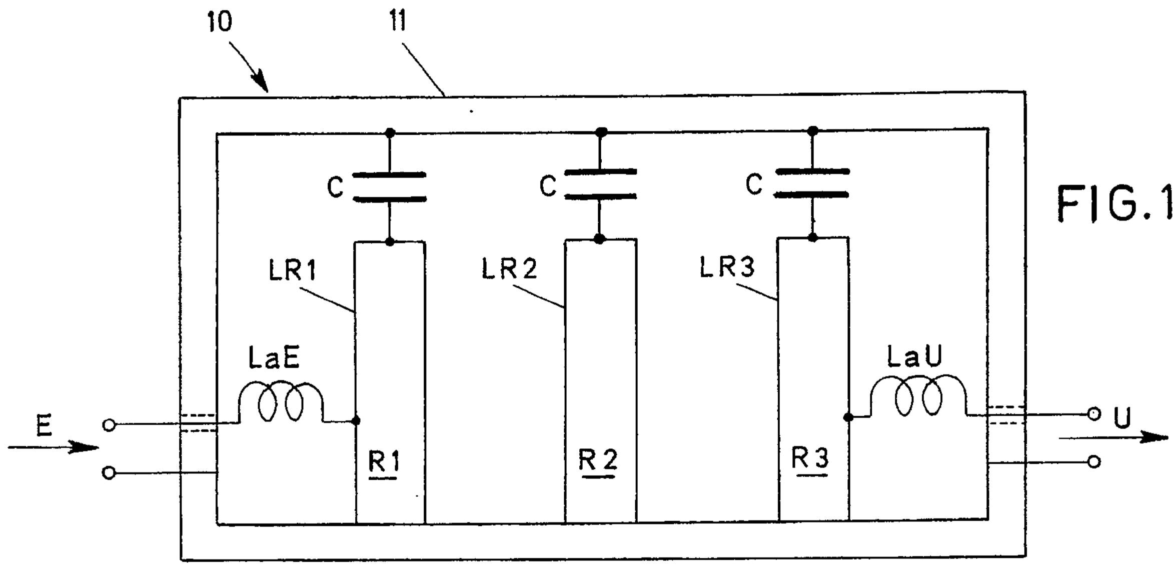


FIG.1

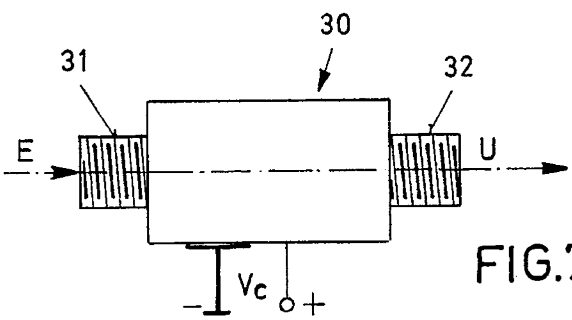


FIG.7

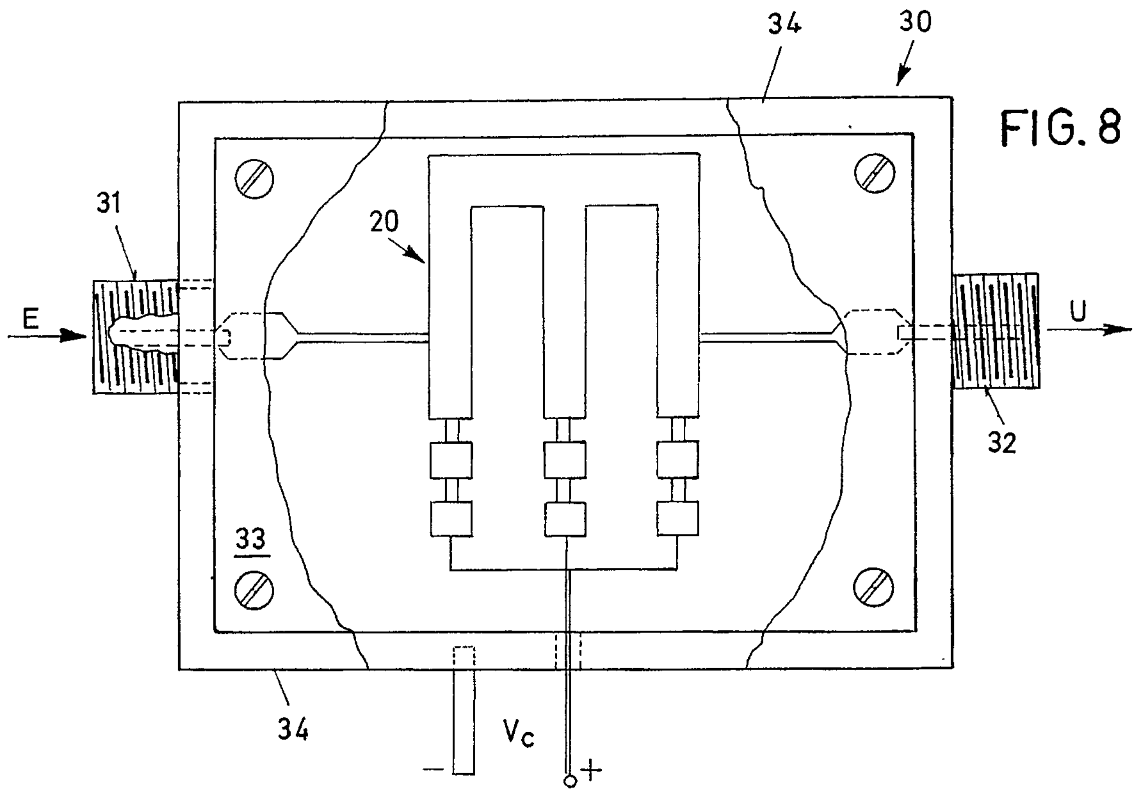


FIG. 8

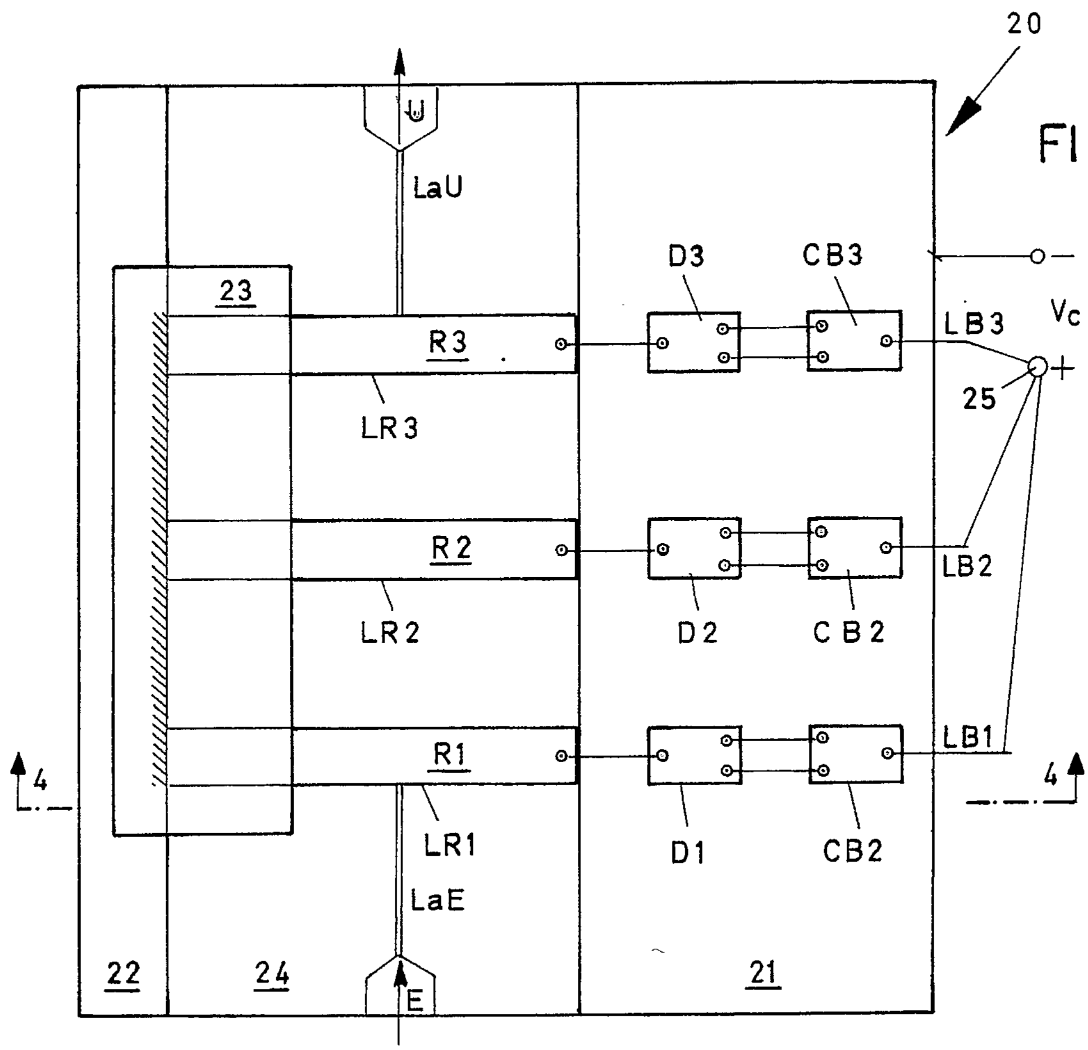


FIG. 2

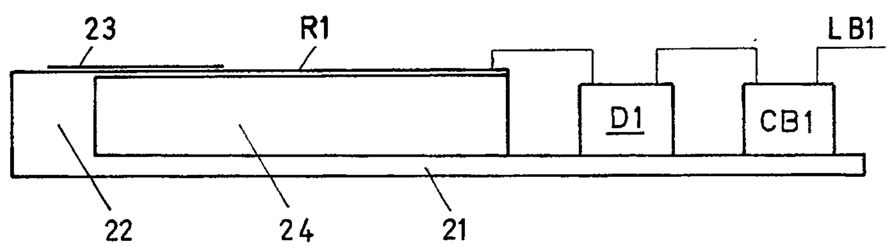


FIG. 3

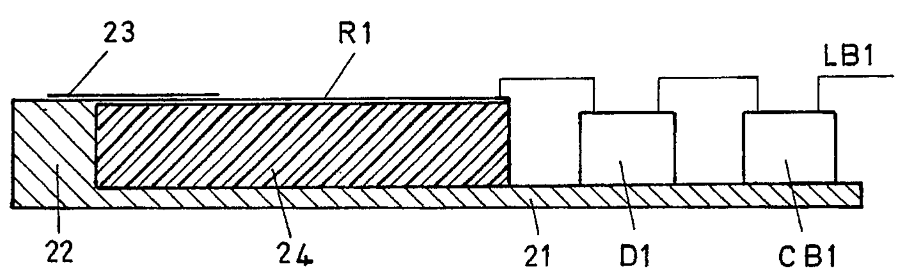
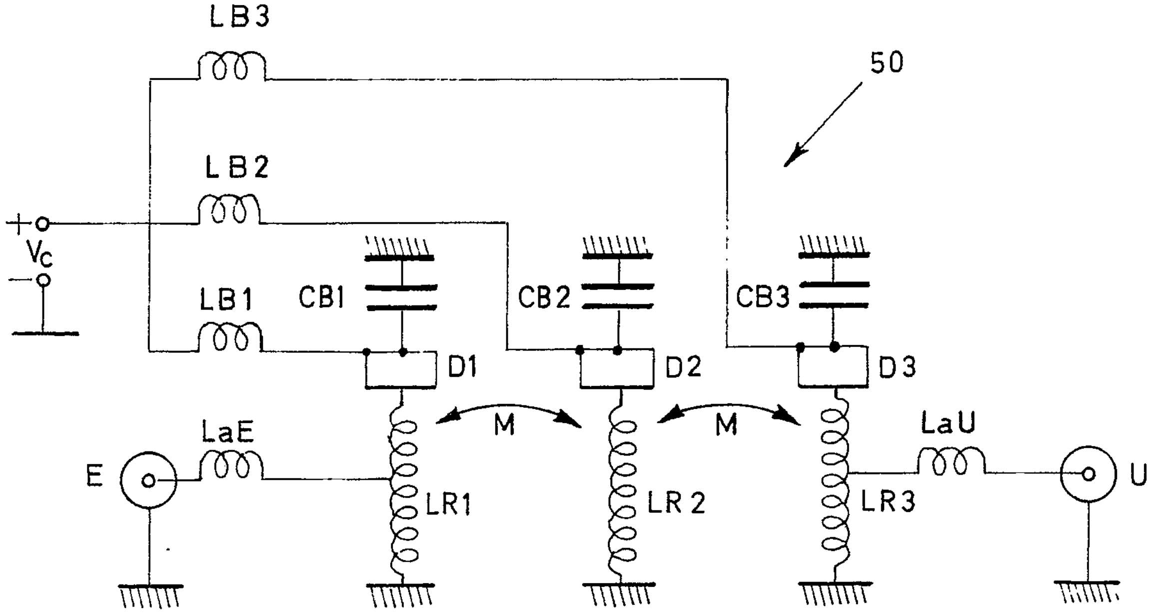


FIG. 4

FIG. 5


LB3
50
LB2
+
Vc
−
LB1
CB1
CB2
CB3
D1
D2
D3
M
M
LaE
E
LR1
LR 2
LR3
LaU
U

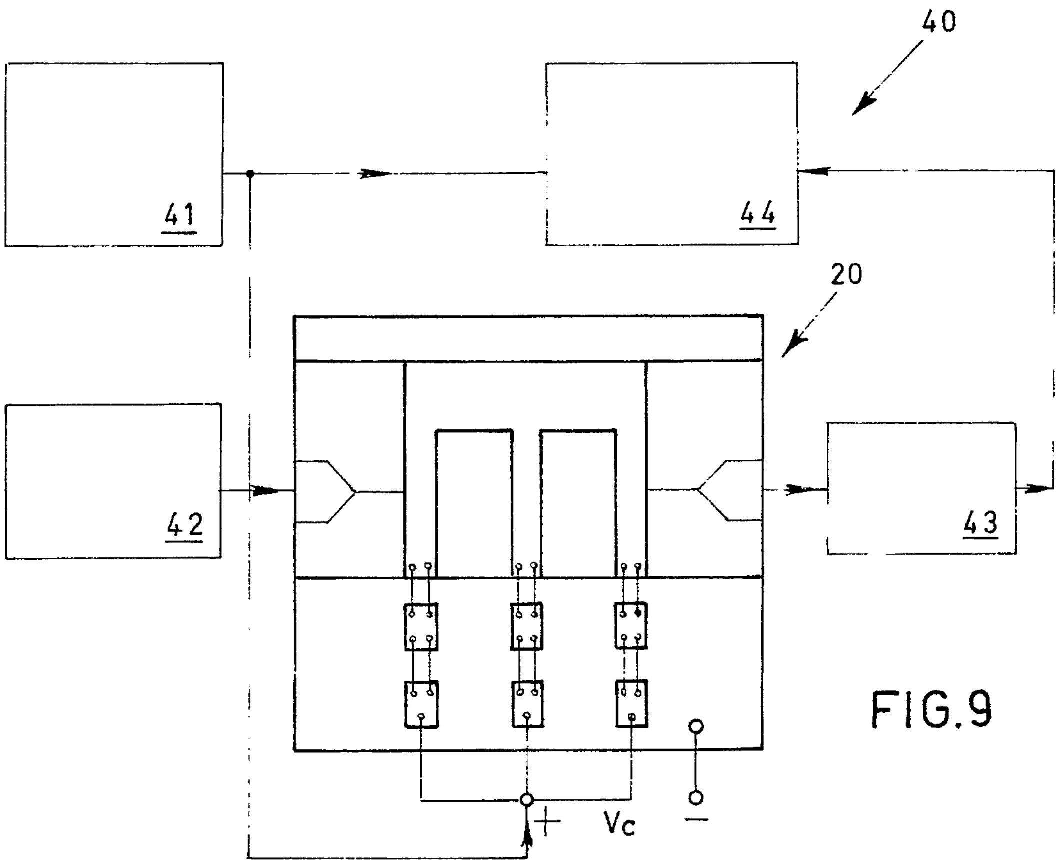

40
41
44
20
42
43
+
Vc
−

FIG. 9

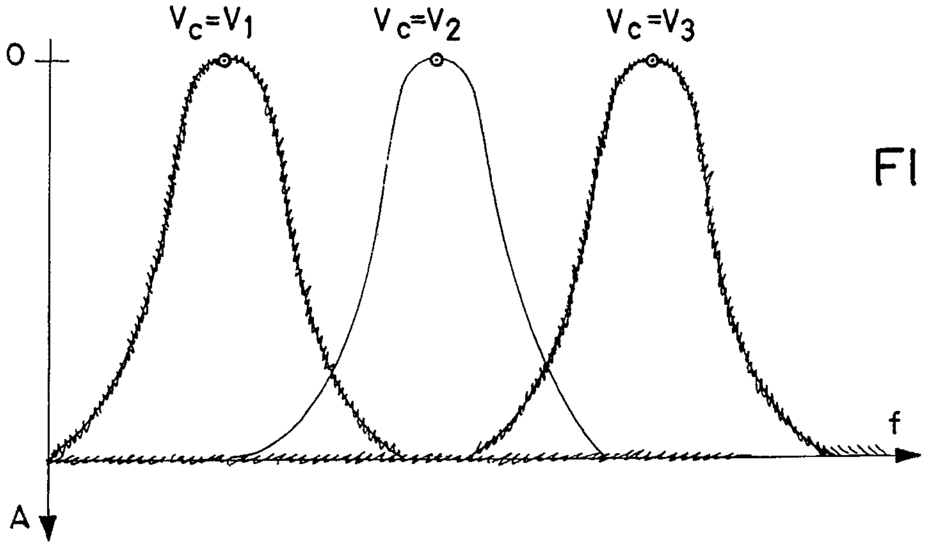
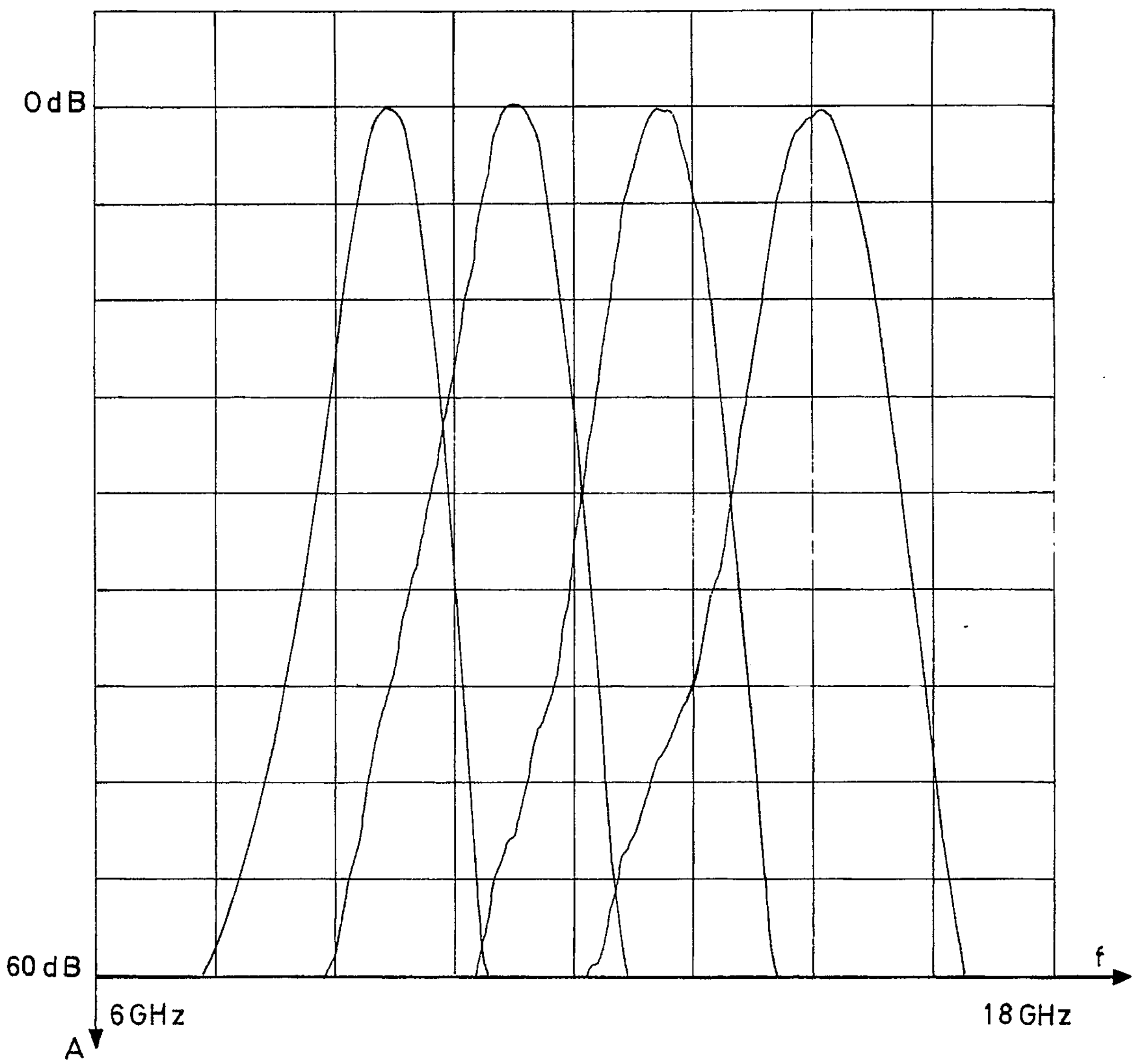


FIG. 6

FIG. 10



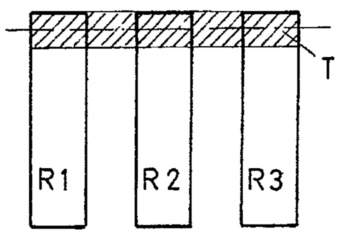


FIG.11a

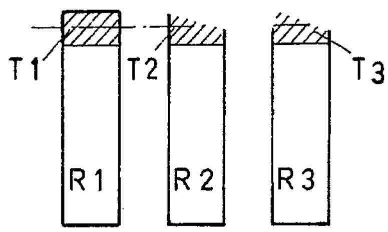


FIG.11b

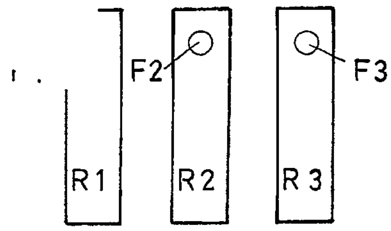


FIG.11c

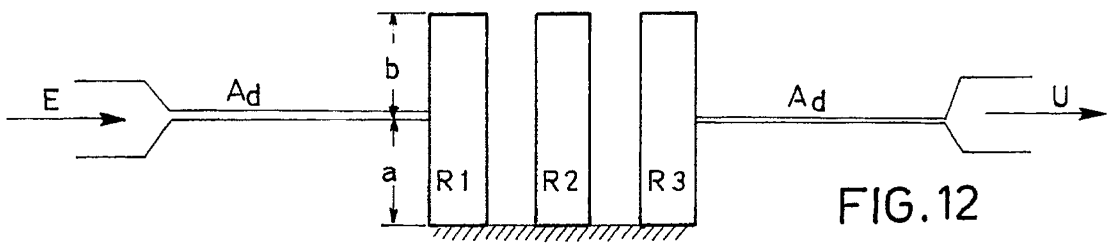


FIG.12

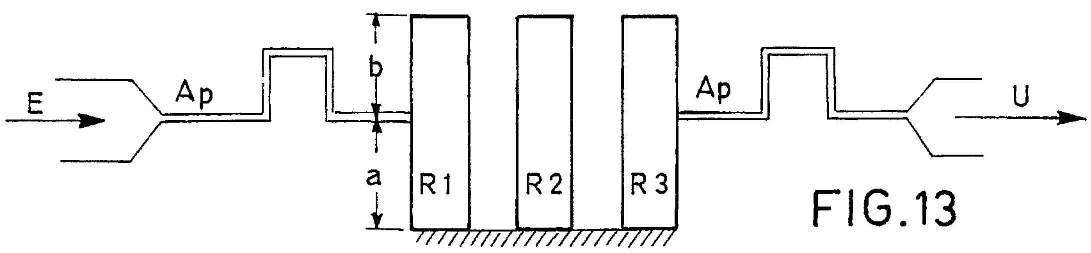


FIG.13

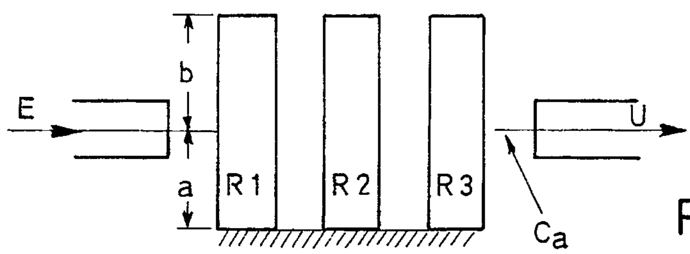


FIG.14

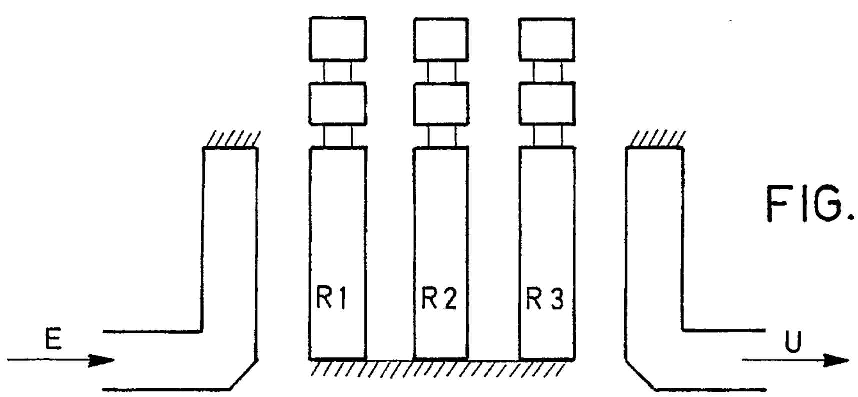


FIG.15

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 83 0542

Page 1

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.5)
Y	MICROWAVE JOURNAL. vol. 22, no. 12, December 1979, DEDHAM US pages 60 - 61; J.A.G.MALHERBE: "An etched digital elliptic filter" * page 60, middle column, line 10 - page 60, right-hand column, line 4; figures 2, 3 *	1, 4	H01P1/205
Y	US-A-4721932 (WEST) * column 3, line 64 - column 4, line 33; figure 4 *	1, 4	
A	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES. vol. 30, no. 9, September 1982, NEW YORK US pages 1354 - 1360; I.C.HUNTER ET AL.: "Electronically tunable microwave bandpass filters" * page 1357, right-hand column, line 7 - page 1359, left-hand column, line 5; figures 9, 10 *	1, 4, 5	
A	US-A-3327255 (BOLLJAHN) * column 2, lines 25 - 70 * * column 3, lines 48 - 55; figures 1, 2, 6 *	1	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	15th EUROPEAN MICROWAVE CONFERENCE-PROCEEDINGS 12-15 september 1988,Stockholm,SE;Microwave Exhibitions and Publishers Ltd,Kent,GB,1988; J.-L.CAZAUX et al.:"The use of double heterojunction diodes in monolithic phase shifters" pages 1005-1010 *page 1005,lines 15-16;page 1007,lines 4-6*	2, 3	H01P
A	1987 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST,Vol.2,june 9-11,1987,Las Vegas,US; IEEE,New York,US,1987 K.CHANG et al.:"Varactor-tuned microstrip ring resonators" pages 867-870 *page 867,right-hand column,lines 7-13;figures 1,4*	4, 5	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 JULY 1990	DEN OTTER A.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document