

June 28, 1938.

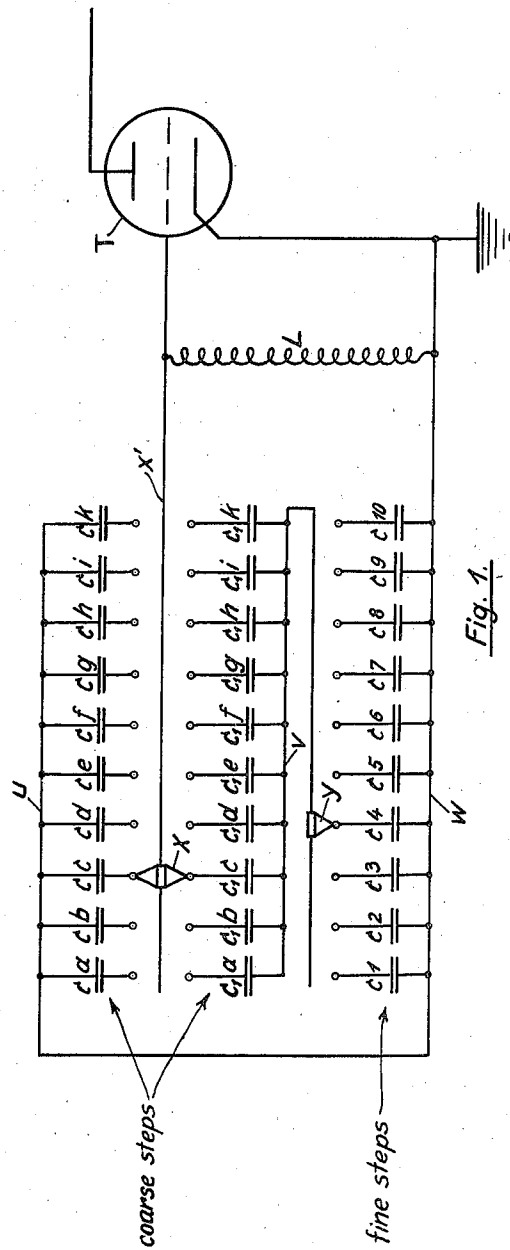
F. SCHWARZER

2,122,183

METHOD OF AND ARRANGEMENT FOR STEPWISE TUNING OF ELECTRIC CIRCUITS

Filed April 8, 1936

2 Sheets-Sheet 1



INVENTOR
Fritz Schwarzer
BY *W. H. H. H. H.*
ATTORNEYS

June 28, 1938.

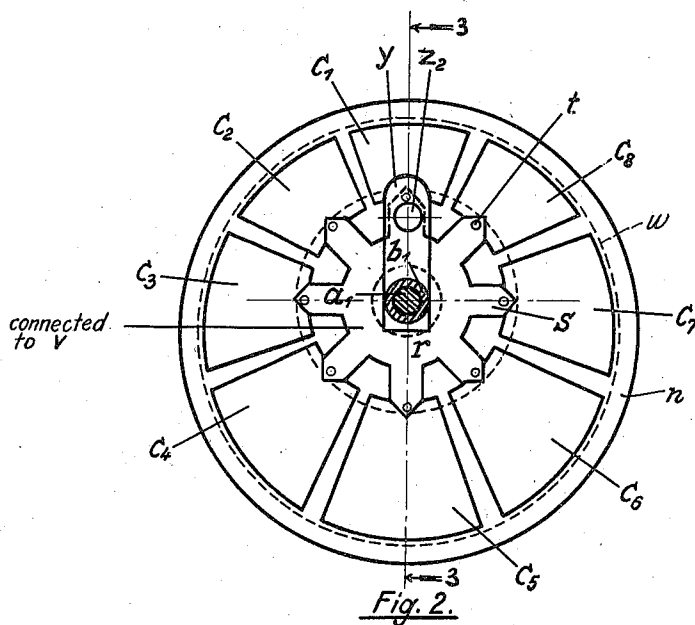
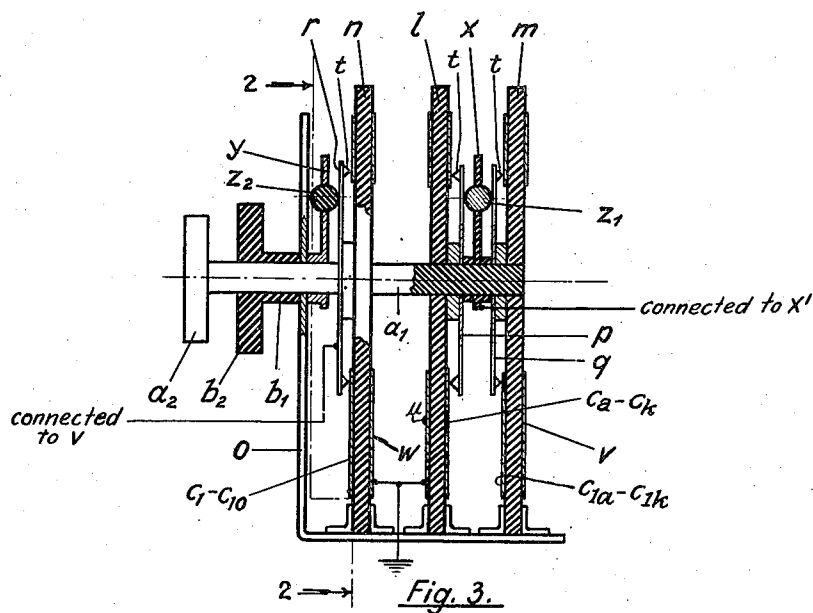
F. SCHWARZER

2,122,183

METHOD OF AND ARRANGEMENT FOR STEPWISE TUNING OF ELECTRIC CIRCUITS

Filed April 8, 1936

2 Sheets-Sheet 2



INVENTOR
Fritz Schwarzer
BY *W. H. H. H. H.*
Attorneys

UNITED STATES PATENT OFFICE

2,122,183

METHOD OF AND ARRANGEMENT FOR
STEPWISE TUNING OF ELECTRIC CIR-
CUITS

Fritz Schwarzer, Berlin-Schoneberg, Germany

Application April 8, 1936, Serial No. 73,380
In Germany April 11, 1935

5 Claims. (Cl. 250-40)

My invention relates to a method of and arrangement for stepwise tuning of electric circuits, such as may be employed for instance in adjusting the frequency of electric circuits in the radio and kindred arts.

It is already known to provide devices especially for tuning high frequency communication circuits with step-wise adjustable tuning elements which operate by two or more selective procedures, and by which stepwise first coarse steps and then within such coarse steps fine steps are adjusted. With such arrangements preferably different fixed capacities are selectively connected into or out of circuit. In such a case, as is well-known, considerable difficulties are encountered in utilizing the same equal fine frequency step arrangement for all coarse steps and to obtain within all coarse steps the same uniform division of the fine frequency steps. Therefore, in such cases additional, separate expedients had to be used heretofore in order to obtain approximately equal frequency steps when the same fine step arrangement is used for all coarse steps. In some of the well-known arrangements of this character the practical construction still encounters considerable difficulties. For instance, the original dimensioning of the different step values is very difficult. Since in such arrangements indirectly also those condenser electrodes act as series capacities which are not connected in circuit at the time, these indirect capacity effects must be taken into consideration and included into the calculation, not only when the system is first calculated, but, in dimensioning in the assembly each condenser electrode to a definite value, the total indirectly acting capacity of the remaining electrodes also varies, so that in progressively dimensioning the different capacity step values of the system the already dimensioned steps change in their effect upon the system so that correct and permanent values cannot be fixed.

The invention refers in particular to such step by step tuning arrangements which involve a similar problem and the invention suggests a solution by which the above-mentioned disadvantages are avoided. According to the invention a combination of parallel and series connected capacities are used whereby the coarse steps are produced by assembling the total capacity of each coarse step from at least two parallel connected capacities. Each fine step is then produced by individual series connection of the selected condenser of a fine step condenser group with only one of the constituent condensers of the selected coarse step. With such an arrangement the relative values of the constituent elements of each coarse step are dimensioned so that on one hand the desired coarse capacity step is produced, and on the other hand the additional selective

series connection of a similar fine step results in the required fine variation of each coarse frequency step at the same fine frequency interval.

My invention is illustrated in the accompanying drawings in which—

Fig. 1 represents diagrammatically the method of arranging the different capacities for coarse and fine step adjustment, and

Figs. 2 and 3 represent a constructive form of such an arrangement of which Fig. 2 represents a sectional elevation on line 2—2 in Fig. 3, and Fig. 3 a sectional elevation on line 3—3 in Fig. 2.

First, the method of connection will be explained with reference to the circuit diagram Fig. 1. The tunable circuit, which may for instance be a portion of a circuit arrangement for a thermionic tube T, consists of an inductance L and of a number of condensers, of which in the present case always three simultaneously partake in the tuning. These condensers are taken from three groups which together constitute the coarse and fine step tuning system, and which in this figure is arranged as a decimal system. The condensers C_a to C_k together with the condensers of group C_{1a} to C_{1k} constitute the coarse steps (which may for instance be 100 kilocycles apart) and the condensers C_1 to C_{10} represent the fine steps (which may be for instance 10 kilocycles apart). The connecting means for effecting the coarse and fine condenser connection which is required for the different steps is represented by the sliding elements x and y assumed in this diagram as sliding contacts. The leads u and v represent the common low potential and ground connections of one side of the condensers of the coarse group C_a to C_k and of the condensers of the fine group C_1 to C_{10} , and the lead v represents the common connection of the low potential side of all condensers C_{1a} to C_{1k} which side may be connected in series with any selected fine step condenser. The fine steps, it will be noted, are thus connected for each coarse step in series with only a portion of the total coarse step capacity. If now the total coarse step capacity of a given step is distributed over the two condensers of the two coarse step groups, appertaining to that step, at a certain ratio which can easily be calculated, the additional selective series connection of the fine step condensers brings about within all coarse steps the same fine frequency intervals. In order to prove this assertion it is only necessary to consider the two extreme cases. If for instance in a given coarse step the constituent capacity portion C_a is made to equal zero, the condenser C_{1a} must include the entire capacity necessary for the frequency appertaining to that step. If in such a case the fine steps are added in order to make fine adjustments these fine steps are thrown in series with the total coarse capacity, and considerable variations in the uniformity of the steps

will occur when this is tried in the different coarse steps. If, on the other hand, the capacity C_{1a} is made to equal zero, the entire required coarse capacity must be embodied in C_a . The additional series connection of fine steps, with C_{1a} equal zero, would in this case not produce any capacity variation at all. From these extreme cases it appears that for each coarse frequency step a suitable intermediate value, located between zero and maximum capacity must exist for each of the two constituent capacities of each coarse step, for which the addition of the same set of fine step series capacities will result in similar frequency intervals in each coarse step.

The manner in which these capacities can be calculated in practice is as follows:—

According to the invention, the total capacity C_R of the circuit is composed for the coarse steps of a parallel capacity C_P , a series capacity C_S and a fine step capacity C_F . If these capacities are combined, we have the resulting value

$$1. \quad C_R = C_P + \frac{C_S \cdot C_F}{C_S + C_F}$$

The capacity of the circuit wires and other circuit elements is for the moment disregarded, since it can be easily correctly added to the parallel capacity C_P .

If we further assume that the inductance of the circuit is constant, the frequency of the oscillatory circuit then becomes dependent only upon the capacity of the circuit (Thomson's formula). The frequency, according to this formula, would then be.

$$35 \quad f = \frac{K}{\sqrt{C_R}}$$

whereby

$$K = \frac{3 \cdot 10^{10}}{2\pi \cdot \sqrt{L}}$$

in other words, K represents a constant which is solely dependent upon L .

We have thus a value for C_R

$$2. \quad C_R = \frac{K^2}{f^2}$$

If now the value for C_R , derived from Equation 1, is substituted in Equation 2, we obtain

$$3. \quad \frac{K^2}{f^2} = C_P + \frac{C_S \cdot C_F}{C_S + C_F}$$

Now in further calculating the values for a practical condenser, according to the invention, a table of the required frequency steps is made, for instance as follows:—

		Fine frequency steps →									
Coarse frequency steps	{	fa1, fa2, fa3, fa4, fa5, fa6, fa7, fa8, fa9, fa10									
		fb1, fb2, ...	 fb10								
		...	...								
		...	...								
		fk1, fk2, fk3, fk4, fk5, fk6, fk7, fk8, fk9, fk10									

We can then set up the following equations. For instance for the first coarse and first fine fre-

quency step we have the equation according to Equation 3:

$$\frac{K^2}{f_{a1}^2} = C_a + \frac{C_{1a} \cdot C_1}{C_{1a} + C_1}; \text{ further,}$$

for the first coarse and second fine step:

$$\frac{K^2}{f_{a2}^2} = C_a + \frac{C_{1a} \cdot C_2}{C_{1a} + C_2}; \text{ and so forth.}$$

Thus ten equations are derived for each coarse step with the unknown values C_a , C_{1a} , C_1 , C_2 , C_3 , C_4 , C_5 , C_6 , C_7 , C_8 , C_9 , C_{10} . If for practical reasons the values C_a and C_{1a} (of C_1 and C_{10}) are assumed, all other unknown values in the ten equations can be calculated, which when combined according to the invention produce ten equally spaced frequencies, constituting the small steps, for instance 10 kc. each.

Thus after the capacity values of the fine steps are determined, the values of C_P and C_S can be determined for each coarse step likewise on the basis of Equation 3. For instance for the second coarse step and first fine step we have the equation

$$\frac{K^2}{f_{b1}^2} = C_b + \frac{C_{1b} \cdot C_1}{C_{1b} + C_1};$$

For the second coarse step, tenth fine step $\frac{K^2}{f_{b10}^2} = C_b + \frac{C_{1b} \cdot C_{10}}{C_{1b} + C_{10}}$; and so forth for the remaining coarse steps.

Thus for each coarse step, the desired frequency range can be determined (for instance 100 kc.). Since, however, each coarse step is divided into ten fine steps according to the above equations, it follows that a change by one fine capacity step will produce at least substantially, if not exactly, the desired fine frequency step (for instance 10 kc.).

For calculating a set of coarse and fine capacities in designing a step by step tuning device according to the present invention, one would proceed as follows in substance in accordance with the preceding mathematical deductions.

First, the desired step values for the coarse and fine capacities are entered into a table in relation to one another. It may here be assumed that the desired intervals of the fine step group amount to about 9 kc. each. The differences between the coarse steps are not exactly 90 kc. but slightly differ from one another for the purpose of equalizing inequalities in the distribution of the wave lengths of the several transmitters over the given frequency range. Thus, the following Table I results, in which the top row represents

TABLE I

Frequencies in kc.

0	9	8	7	6	5	4	3	2	1	F
961	970	979	988	997	1006	1015	1024	1033	1042	K
1054	1063	1072	1081	1090	1099	1108	1117	1126	1135	J
1146	1155	1164	1173	1182	1191	1200	1209	1218	1227	H
1238	1247	1256	1265	1274	1283	1292	1301	1310	1319	G
1328	1337	1346	1355	1364	1373	1382	1391	1400	1409	F
1419	1428	1437	1446	1455	1464	1473	1482	1491	1500	E
1510	1519	1528	1537	1546	1555	1564	1573	1582	1591	D
1600	1609	1618	1627	1636	1645	1654	1663	1672	1681	C
1691	1700	1709	1718	1727	1736	1745	1754	1763	1772	B
1781	1790	1799	1808	1817	1826	1835	1844	1853	1862	A

Then the capacities appertaining to each frequency are calculated. The smallest tuning capacity for the given circuit was assumed to be 135 cm. with which is coordinated the highest frequency to which the given circuit can be tuned, namely, 1862 kc. (A—1, Table I). These calculated values are then entered into the following Table II.

TABLE II

Capacities in cm.

0	9	8	7	6	5	4	3	2	1	F
506.81	497.45	488.34	479.48	470.86	462.47	454.31	446.37	438.62	431.07	K
421.32	414.21	407.30	400.53	393.94	387.52	381.23	375.14	369.16	363.32	J
356.39	350.86	345.45	340.17	335.01	329.97	325.04	320.21	315.49	310.89	H
305.39	300.99	296.70	292.49	288.37	284.33	280.40	276.52	272.74	269.04	G
265.40	261.84	258.34	254.92	251.58	248.28	245.06	241.9	238.8	235.7	F
232.45	229.53	226.66	223.85	221.09	218.38	215.72	213.1	210.49	208.02	E
205.27	202.85	200.47	198.13	195.83	193.57	191.34	189.16	187.02	184.90	D
182.83	180.79	178.78	176.81	174.88	172.96	171.08	169.24	167.42	165.63	C
163.69	161.95	160.26	158.58	156.93	155.31	153.71	152.14	150.59	149.06	B
147.56	146.08	144.62	143.18	141.77	140.37	139.00	137.65	136.31	135.00	A

For the further calculation there should be deducted from the foregoing calculated values a constant value representing the capacity distributed over the whole circuit, which value in the present case is assumed 80 cm. Thus, the actual tuning capacity values result which are entered in the following Table III.

TABLE III

Capacities in cm.

0	9	8	7	6	5	4	3	2	1	F
426.81	417.45	408.34	399.48	390.86	382.47	374.31	366.37	358.62	351.07	K
341.32	334.21	327.30	320.53	313.94	307.52	301.23	295.14	289.16	283.32	J
276.39	270.86	265.45	260.17	255.01	249.97	245.04	240.21	235.49	230.89	H
225.39	220.99	216.70	212.49	208.37	204.33	200.39	196.52	192.74	189.04	G
185.40	181.84	178.34	174.92	171.58	168.28	165.06	161.90	158.80	155.76	F
152.45	149.53	146.66	143.85	141.09	138.38	135.72	133.10	130.54	128.02	E
125.27	122.85	120.47	118.13	115.83	113.57	111.34	109.16	107.02	104.90	D
102.83	100.79	98.78	96.81	94.88	92.96	91.08	89.24	87.42	85.63	C
83.69	81.95	80.26	78.58	76.93	75.31	73.71	72.14	70.59	69.06	B
67.56	66.08	64.62	63.18	61.77	60.37	59.00	57.65	56.31	55.00	A

For the further calculation, the following additional designations are introduced:

If these equations are solved according to their unknown, we have

$$IV. G_S = \frac{(F_a + F_b)(C_a - C_b) \pm \sqrt{(F_a - F_b)(C_a - C_b)4F_a F_b - (F_a - F_b)(C_a - C_b)}}{2(F_a - F_b) - (C_a - C_b)}$$

The capacity of the capacity combination C provided with the index of the coarse step (A—K) and the fine step (1—0)

The parallel capacity G_P with the index of the coarse step (A—K)

The series capacity G_S with the index of the coarse step (A—K)

The capacity of the fine step F with the index of the fine step (1—0)

The fundamental equation on which the further calculation is based is—

$$I. C_R = G_P + \frac{G_S F}{G_S + F}$$

For practical reasons the condition was required that the values of largest individual capacities should be approximately all of the same order

$$G_{PK} = G_{SK} = F_0$$

If this condition is entered in Equation I, we have

$$II. G_{PK} = G_{SK} = F_0 = \frac{C_{KO}}{1.5}$$

Assuming that the capacities of a coarse step are known, the fine steps are

$$III. F = \frac{G_S(C_R - G_P)}{G_S - (C_R - G_P)}$$

$$C_a = G_P + \frac{G_S F_a}{G_S + F_a}$$

$$C_b = G_P + \frac{G_S F_b}{G_S + F_b}$$

$$V. G_P = C_a - \frac{G_S F_a}{G_S + F_a}$$

Thus, all equations for the division of the capacities are determined.

The numerical evaluation was made as follows. First, after the coarse step K, the fine steps F_1 and F_0 were calculated. From the values obtained were then determined the parallel—and the series capacities for the coarse step H (G_{PH} , G_{SH}) and thereafter definitely the fine steps F_1 — F_0 . From the fine steps F_0 and F_2 the coarse steps A—J are calculated. In order to determine the deviations on the step K, the capacity G_{PK}

was increased a corresponding amount. Thus, the following values were obtained:—

	G_P	G_S	F
5	20.811	55.53	86.832
	32.672	61.686	98.41
	46.735	69.357	111.40
	63.298	78.678	126.330
10	83.357	90.722	143.264
	107.691	106.33	162.81
	137.261	127.23	185.61
	174.877	157.81	212.585
	222.701	204.605	244.99
	285.85	284.54	284.54

In order to determine the deviations, all capacities are combined according to the system described hereinbefore, and the resulting values are entered in the following Table IV.

TABLE IV
Capacities in cm.

	0	9	8	7	6	5	4	3	2	1	F
25	428.12	417.496	407.53	398.18	389.40	381.138	373.336	365.952	358.968	352.379	K
	341.709	334.210	326.969	320.033	313.372	306.979	300.847	294.876	289.160	283.570	J
	276.387	270.86	265.451	260.17	255.011	249.98	245.042	240.234	235.491	230.912	H
	225.175	220.990	216.853	212.746	208.676	204.645	200.650	196.680	192.750	188.878	G
	185.086	181.840	178.571	175.296	172.011	168.724	165.427	162.115	158.795	155.490	F
	152.114	149.530	146.914	144.267	141.587	138.878	136.136	133.353	130.540	127.704	E
	124.949	122.55	120.723	118.554	116.340	114.085	111.781	109.424	107.020	104.574	D
30	102.499	100.79	99.050	97.226	95.371	93.468	91.511	89.492	87.42	85.293	C
	83.366	81.95	80.483	78.972	77.406	75.791	74.119	72.38	70.589	68.736	B
	67.27	66.08	64.84	63.55	62.217	60.829	59.38	57.87	56.31	54.681	A

The differences $\pm$ between the required values and the actually resulting values are entered in the following Table V.

TABLE V
Capacities in cm.

	0	9	8	7	6	5	4	3	2	1	F
40	+1.31	+0.046	-0.81	-1.30	-1.46	-1.33	-0.97	-0.42	+0.35	+1.31	K
	+0.39	± 0	-0.33	-0.5	-0.57	-0.54	-0.38	-0.26	± 0	+0.35	J
	± 0	± 0	± 0	± 0	± 0	+0.01	± 0	+0.02	± 0	+0.02	H
45	-0.21	± 0	+0.15	+0.26	+0.31	+0.32	+0.26	+0.16	+0.01	-0.16	G
	-0.30	± 0	+0.23	+0.38	+0.43	+0.44	+0.37	+0.21	± 0	-0.27	F
	-0.34	± 0	+0.25	+0.42	+0.50	+0.50	+0.42	+0.25	± 0	-0.32	E
	-0.32	± 0	+0.25	+0.42	+0.51	+0.52	+0.44	+0.26	± 0	-0.33	D
	-0.33	± 0	+0.25	+0.42	+0.49	+0.51	+0.43	+0.25	± 0	-0.34	C
	-0.32	± 0	+0.22	+0.39	+0.48	+0.48	+0.41	+0.24	± 0	-0.32	B
	-0.29	± 0	+0.22	+0.37	+0.45	+0.46	+0.38	+0.22	± 0	-0.32	A

The largest capacity deviation exists at the value K₈, amounting to 1.46 cm. This would correspond with a frequency difference of 1.56 kc. The greatest frequency difference exists, on the other hand, in the step A, since here the greatest relative capacity difference appears. At A₈ the error is +0.46 cm. or -2.95 kc.

In the following Table VI are entered the tuning deviations in kc. Errors below 0.5 kc. are denoted by 0, since they may be neglected for all practical purposes.

TABLE VI
Frequency deviations in kc.

	0	9	8	7	6	5	4	3	2	1	F
65	-1.25	0	+0.75	+1.25	+1.50	+1.50	+1.00	0	0	-1.5	K
	0	0	0	+0.75	+0.75	+0.75	+0.5	0	0	-0.5	J
	0	0	0	0	0	0	0	0	0	0	H
	0	0	0	-1.5	-0.75	-0.75	-0.5	0	0	0	G
70	+0.75	0	-0.5	-1.0	-1.25	-1.25	-1.0	-0.5	0	+0.75	F
	+1.0	0	-0.75	-1.25	-1.50	-1.50	-1.25	-0.75	0	+1.25	E
	+1.25	0	-1.00	-1.50	-2.00	-2.00	-1.75	-1.00	0	+1.50	D
	+1.50	0	-1.00	-2.00	-2.25	-2.50	-2.00	-1.25	0	+1.75	C
	+1.75	0	-1.25	-2.00	-2.50	-2.75	-2.25	-1.50	0	+2.00	B
	+1.75	0	-1.25	-2.00	-2.75	-3.00	-2.50	-1.50	0	+2.25	A

The idea involved in such an arrangement as shown in Fig. 1 may be embodied in a practical apparatus in the manner shown in Figs. 2 and 3.

Referring to these figures, the three different groups of condensers above-mentioned are arranged separately on three circular carriers l , m , n , of suitable dielectric material, for instance ceramic material of well-known type, and so that the high potential electrodes of condensers C_a to C_k are located on the side plate l , facing plate m , the high potential electrodes of the condensers C_{1a} to C_{1k} are arranged on the side on plate m facing plate l , and the high potential electrodes of condensers C_1 to C_{10} are mounted on the front side of plate n . These individual electrodes may consist of suitable metal, such as silver, and may be attached to their respective carrier plates by spraying or other suitable means. Their exact

areas may be finally adjusted by grinding or scraping away surplus portions, a method of adjustment, well-known in the manufacture of

ceramic condensers. The three carrier plates are mounted in parallel to one another at suitable distances apart and are fixed in a frame o . To plates l , m , and n on the side where the high potential electrodes are located are fixed respectively the conducting contact stars p , q , r , the shape of which is shown with respect to the star r in Fig. 2. The arms s of each of these stars constitute yielding tongues, as shown in Fig. 2, which protrude severally over the sector-shaped high potential condenser electrodes, as shown in both

figures, and which are provided at these overlapping portions each with a silver contact point *t*. As may be further noted from Fig. 2, the contact stars *p*, *q*, *r* are mounted eccentrically with respect to the circular carriers *l*, *m*, *n* on which latter the condenser electrode fields are arranged in eccentric sector fashion with different areas. The low potential counterelectrodes for the electrode sectors on carriers *l*, *m*, *n* constitute closed metallic rings *u*, *v*, *w*, indicated in Fig. 1 with correspondingly similar letters, which in that figure are meant to include the low potential condenser plates as well as the interconnecting leads. The switching elements *x* and *y* in Fig. 1 correspond in Figs. 2 and 3 to the rotatable arms *x* and *y*, together with the pressing balls *z*₁, *z*₂ respectively, of which ball *z*₂ is made of insulating material for purely constructive reasons. Arm *x* is mounted insulated on the rotatable shaft *a*₁ which carries at one end a hand knob *a*₂. This arm constitutes one of the terminals of the entire condenser arrangement which is connected, as shown in Fig. 1, to lead *x'* which is in turn connected to the high potential end of the inductance *L*. In Fig. 3 this connection is merely indicated by an arrowed line with the legend "To *x'*". The contact arm *y* is mounted on the hollow shaft *b*₁ which is carried on shaft *a*₁, and shaft *b*₁ is provided with a hand knob *b*₂. Of course, in place of these hand knobs any other suitable driving means for these two shafts may be used in accordance with the mechanism in which the condenser system may be mounted.

If now for instance arm *x* is rotated by operating its hand knob *a*₁, the contact ball *z*₁ carried by that arm will press oppositely located tongues of stars *p* and *q*, between which arm *x* is mounted, outwardly as soon as it encounters these tongues and thereby press these tongues with their respective contact tips *t* against their oppositely located condenser electrode sectors. In this manner two appertaining condensers of the two coarse groups *C*_a to *C*_k and *C*_l to *C*_k are connected in parallel, the same as if in Fig. 1 the slide *x* had been moved for instance into the position shown in that figure. If now by rotating arm *y* into the desired position, its contact ball *z*₂ will press tip *t* of the particular tongue of contact star *r* which it encounters against the oppositely disposed line step condenser sector of the fine step group *C*₁ to *C*₁₀, and thereby connect a particular fine step condenser in series with the previously selected parallel connected coarse step condenser of group *C*_l to *C*_k. For instance, as shown in Fig. 1 the slide *y* may connect the fine step *C*₄ in series with the constituent condenser *C*₁₀ of the total coarse capacity step *C*₀, *C*₁₀.

For simplicity of illustration the carrier plate *n* shown in Fig. 2 in front elevation is provided with only eight sectors *C*₁ to *C*₈ instead of using the decimal system shown in Fig. 1. This is, of course, only a matter of design.

The essential advantage of the arrangement shown for instance in Figs. 2 and 3 is that within the capacity groups no separate connections are necessary. Aside from the modifications shown and described hereinabove numerous additional modifications of this arrangement may be made within the scope of the present invention, involving a mixed series and parallel connection of capacities as tuning elements in oscillatory circuits or the like, for obtaining uniform or approximately uniform frequency steps. For instance, according to the invention it is also pos-

sible to arrange a third group of condensers which constitute a further subdivision of the fine group *C*₁ to *C*₁₀, and which permit within that group stepwise adjustments from kilocycle to kilocycle.

I claim:

1. Means for stepwise tuning an electric circuit by capacity variation at substantially uniform frequency intervals, comprising a group of individual coarse step capacities and at least one group of selected individual finer step capacities constituting the substeps for the coarse capacities, each of said coarse capacities being divided into two parallel-connected individual constituent capacities at such a ratio with respect to the fine step capacities, that each selected finer step capacity, when connected in series with one of the constituent capacities of any selected coarse step, produces the same fine step frequency intervals, whereby the same group of finer step capacities can be used as substeps for each coarse step capacity to produce substantially the same finer step frequency intervals for all coarser capacity steps.

2. Means for stepwise tuning an electric circuit by capacity variation at uniform frequency intervals, comprising a group of individual coarse step capacities and at least one group of individual finer step capacities constituting the substeps for the coarse capacities, each of said coarse capacities being divided with respect to the finer step capacities at such a ratio into two parallel-connected individual constituent capacities that each selected finer step capacity, when connected in series with one of the constituent capacities of any selected coarse step, produces the same fine step frequency intervals, a contact spring for each constituent capacity of each coarse step, and means for simultaneously actuating the contact springs of the constituent capacities of the selected coarse step to connect said capacities in parallel into the circuit, a contact spring for each finer step capacity and means for actuating the spring of the selected finer step capacity to connect it in series with one of the constituent capacities of the selected coarse step, whereby the same group of finer step capacities can be used as substeps for each coarse step capacity to produce substantially the same finer step frequency intervals for all coarse capacity steps.

3. Means for stepwise tuning an electric circuit by capacity variation at uniform frequency intervals, comprising a group of individual coarse step capacities and at least one group of individual fine step capacities constituting the substeps for the coarse capacities, each of said coarse capacities being divided with respect to the finer step capacities at such a ratio into two parallel-connected individual constituent capacities that each selected finer step capacity, when connected in series with one of the constituent capacities of any selected coarse step, produces the same fine step frequency intervals, a disc of dielectric material having one of the electrodes of one set of constituent capacities of all coarse steps mounted on one side in sector fashion and carrying on the opposite side an annulus of conductive material representing the other electrode in common to all first-named sector electrodes, a second similarly constructed disc of dielectric material having the electrodes of the other set of constituent capacities mounted on it in similar sector and annulus fashion, said discs being spaced apart and fixed in parallel to one another so that the sectors of the constituent capacities of each coarse step are located opposite

one another, contact means rotatable between said discs for connecting the constituent sectors of the selected coarse step simultaneously in parallel into the circuit, a third disc of dielectric material constructed similar to the previously mentioned discs and having the electrodes of the fine step capacities mounted on it in similar sector and annulus fashion, and contact means rotatable over the sectorized portion of said disc for connecting the selected fine capacity in series with one of the constituent capacities of the selected coarse step, whereby the same group of fine step capacities can be used as substeps for each coarse step capacity to produce substantially the same fine step frequency intervals for all coarse capacity steps.

4. Means for stepwise tuning an electric circuit by capacity variation at uniform frequency intervals, comprising a group of individual coarse step capacities and at least one group of individual fine step capacities constituting the substeps for the coarse capacities, each of said coarse capacities being divided with respect to the fine step capacities at such a ratio into two parallel-connected individual constituent capacities that each selected finer step capacity, when connected in series with one of the constituent capacities of any selected coarse step, produces the same fine step frequency intervals, a disc of dielectric material having one of the electrodes of one set of constituent capacities of all coarse steps mounted on one side in sector fashion and carrying in the opposite side an annulus of conductive material representing the other electrode in common to all first-named sector electrodes, a second similarly constructed disc of dielectric material having the electrodes of the other set of constituent capacities mounted on it in similar sector and annulus fashion, said discs being spaced apart and fixed in parallel to one another so that the sectors of the constituent capacities of each coarse step are located opposite one another, a star-shaped contact spring fixed on each disc and

having each of its arms extending over one of the constituent electrode sectors on said disc, and means rotatable between said discs for simultaneously actuating the contact arms for the constituent capacities of the selected coarse step, to connect said capacities simultaneously in parallel into the circuit, a third disc of dielectric material constructed similar to the previously mentioned discs and having the electrodes of the fine step capacities mounted on it in similar sector and annulus fashion, a star-shaped contact spring fixed on said disc and having each of its arms extending over one of the sectors of the fine step capacities, and means rotatable over said arms for actuating the contact arm of the selected fine step to connect the selected fine step capacity in series with one of the constituent capacities of the selected coarse step, whereby the same group of fine step capacities can be used as substeps for each coarse step capacity to produce substantially the same fine step frequency intervals for all coarse capacity steps.

5. Means for stepwise tuning an electric circuit by means of a plurality of fixed capacities serving as coarse tuning steps, each capacity being divided at a suitable ratio into a plurality of parallel-connected portions, and a plurality of capacities serving as fine tuning steps, said tuning means comprising means for connecting the two parallel portions of a selected coarse step into the circuit and means for connecting into the circuit for each selected coarse step one of the fine step capacities in series with one of the constituent portions of the selected coarse step, to produce for each tuning step a definite total capacity resulting from a plurality of capacities in mixed series-parallel connection, the relative values of the parallel connected portions of each coarse step being dimensioned with respect to the fine step capacities so that the same finer step capacities produce in all coarse steps substantially the same fine step frequency intervals.

FRITZ SCHWARZER.