

Feb. 18, 1947.

A. H. TURNER

2,415,977

SUPERHETERODYNE CONVERTER

Filed March 8, 1943

2 Sheets-Sheet 1

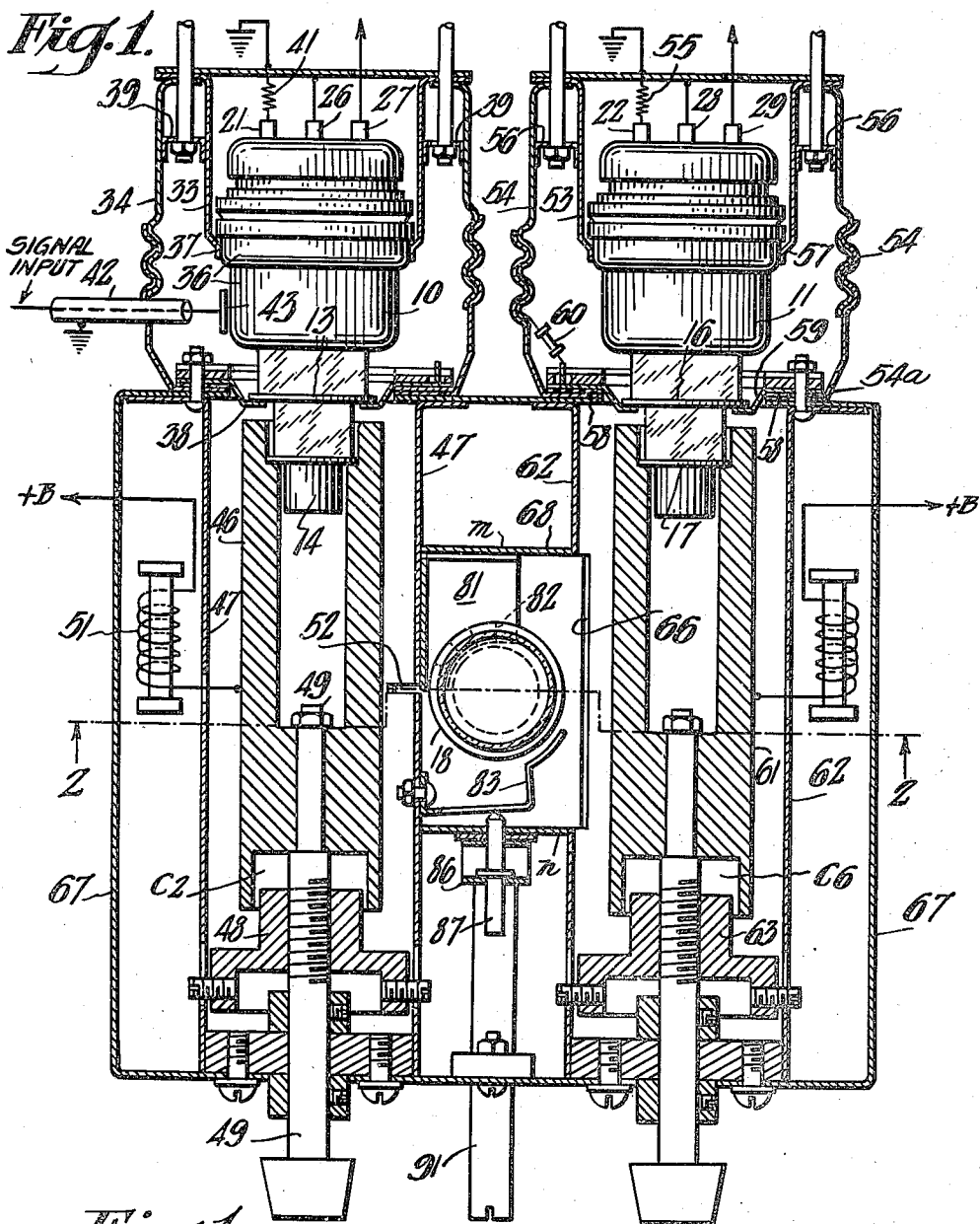
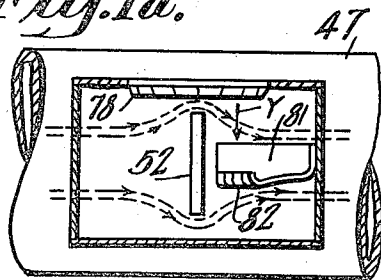


Fig. 1a.



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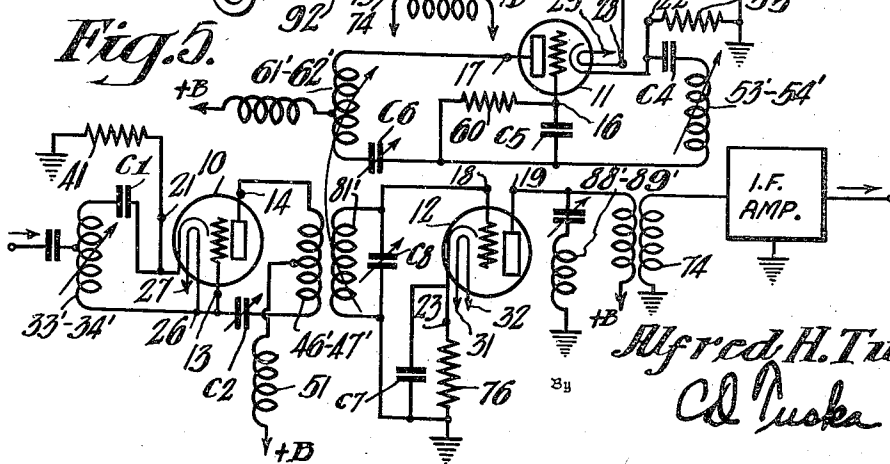
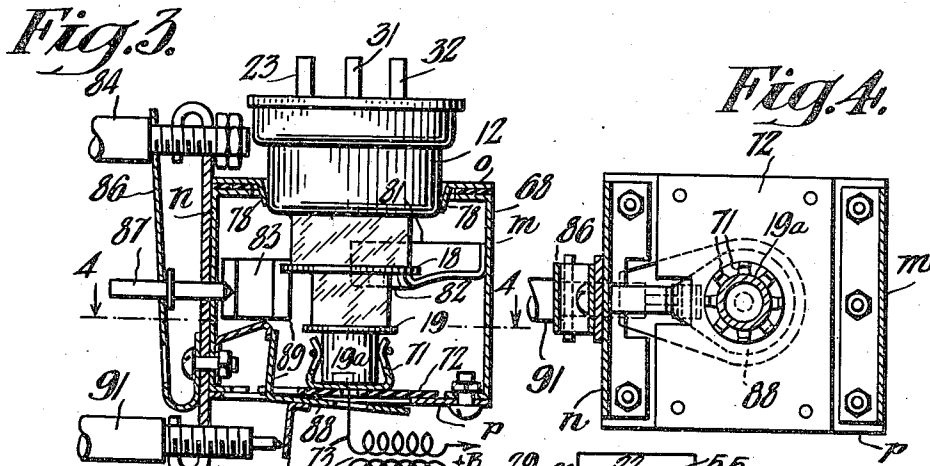
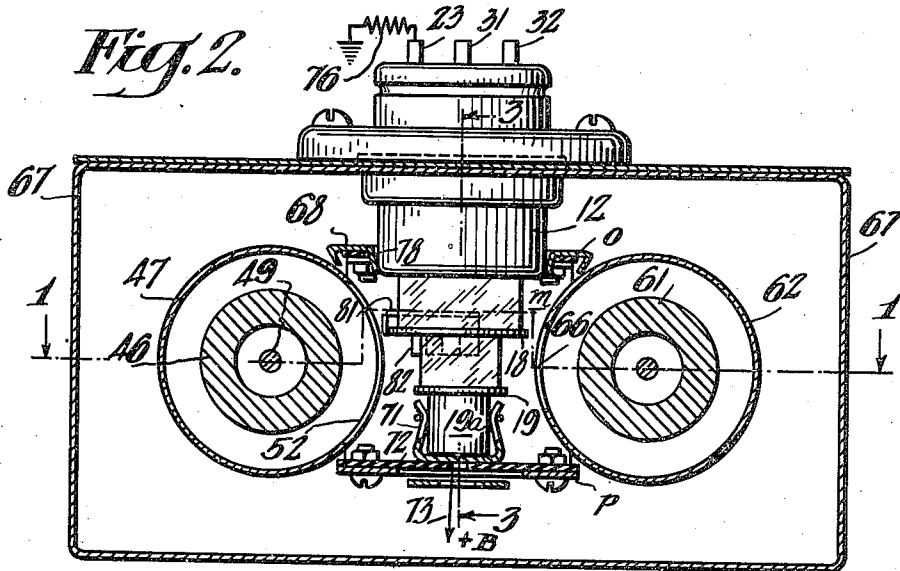
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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SUPERHETERODYNE CONVERTER

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6 Claims. (Cl. 250—20)

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My invention relates to radio receivers for receiving high frequency signals such as centimeter wave signals. It relates particularly to a radio-frequency amplifier, local oscillator and detector unit for converting the incoming radio-frequency signals to intermediate-frequency signals.

The usual method of coupling the radio-frequency amplifier and the local oscillator to the detector or converter tube has been by using untuned coaxial lines. This has the disadvantage that radio-frequency signal energy is lost in both of these coaxial lines, and oscillator energy is also lost in both of the lines since both lines are coupled to the converter tube.

An object of the present invention is to provide a frequency converter unit in which the energy loss is a minimum. A further object of the invention is to provide an improved superheterodyne converter unit for the reception of ultra high frequencies.

In a preferred embodiment of the invention the radio-frequency amplifier and the local oscillator are of the type having concentric line plate circuits. These concentric line circuits are positioned parallel to each other and the detector or converter tube is located between them and inside a box-like compartment of conducting material which bridges the two parallel lines. Windows or openings are provided in the outer conductors of the two plate circuits; these windows form openings in the bridging compartment. Potential differences appear across the conductor openings to circulate radio-frequency and oscillator currents which excite the grid circuit of the detector tube.

The invention will be better understood from the following description taken in connection with the accompanying drawings in which

Figure 1 is a view of one embodiment of the invention, the view being partly in section taken on the line 1—1 of Fig. 2.

Figure 1a is a view that is referred to in explaining the operation of the invention.

Figure 2 is a view taken on the line 2—2 of Fig. 1.

Figure 3 is a view taken on the line 3—3 of Fig. 2.

Figure 4 is a view taken on the line 4—4 of Fig. 3, and

Figure 5 is a circuit diagram showing the equivalent circuit diagram for the unit illustrated in Figs. 1 to 4.

In the several figures similar parts are indicated by similar reference characters.

Referring to the drawings, particularly to Figs.

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1 and 2, the radio-frequency amplifier tube 10, the oscillator tube 11 and the detector tube 12 are triodes of the "light-house" type, RCA 446A or General Electric type ZP 464, for example, although it should be understood that the invention is not limited to this specific type of tube. The grid and plate terminals of the tube 10 are the rings 13 and 14, respectively, which are supported by glass sections of the tube. Corresponding terminals for the tubes 11 and 12 are shown at 16, 17 and 18, 19, respectively. The cathode terminals for the tubes 10, 11 and 12 are shown at 21, 22 and 23, respectively. The heater terminals for the cathodes of tubes 10, 11 and 12 are shown at 26, 27, at 28, 29 and at 31, 32, respectively. The various electrode terminals are also indicated in the equivalent circuit diagram of Fig. 5.

The R.-F. amplifier tube 10 has a tuned grid-cathode circuit comprising an inner conductor 33 and an outer conductor 34 which form a concentric line. The connection from the cathode of tube 10 to the end of the inner conductor 33 for the high frequency signal is through internal tube capacity between the cathode and the outer metal shell 36 and through the metal fingers 37 to conductor 33. This internal capacity is indicated at C1 in Fig. 5. The connection from the grid of tube 10 to the end of the outer conductor 34 is from the grid terminal 13 to metal fingers 38 which are conductively connected to the end of conductor 34.

The grid-cathode line 33—34 is tuned by means of a slidable shorting ring 39. In Fig. 5 the line 33—34 is represented by the lumped inductance 33'—34'. Biasing is provided by means of a cathode resistor 41. The received R.-F. signal is applied to the R.-F. amplifier through a concentric line 42 which has its inner conductor capacitively coupled to the tube shell 36 by means of a small capacitor plate 43.

The tuned plate circuit is a concentric line comprising an inner conductor 46 having one end connected to the plate terminal 14 and an outer conductor 47 having one end connected to the grid terminal 13 through the fingers 38. The line 46—47 is tuned by means of a plug 48 which may be moved longitudinally by rotating a threaded insulating rod 49 to change the capacity C2 at one end of the line. Operating voltage is applied to the plate terminal 14 through an R.-F. choke coil 51. In Fig. 5 the tuned line 46—47 is represented by the lumped inductor 46'—47'. A narrow window or opening 52 in one side of the

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outer conductor 47 is provided for coupling into the detector tube 12 as explained hereinafter.

The oscillator tube 11 preferably is connected to operate as an oscillator of the grounded grid type as described and claimed in my copending application Serial No. 428,665, filed January 29, 1942, and entitled Oscillator.

The oscillator has a tuned cathode-grid circuit comprising an inner conductor 53 and a concentric outer conductor 54 which form a concentric line. This line is tuned by means of a shorting ring 55. The connection from the inner conductor 53 to the cathode of tube 11 is through the fingers 57 and through internal tube capacity, the latter being indicated at C4 in Fig. 5. The tuned line 53—54 is represented by the lumped inductor 53'—54' in Fig. 5. A suitable cathode bias resistor 55 is connected between cathode terminal 22 and ground.

In this oscillator design, the connection between the grounded outer conductor 54 and the grid terminal 16, instead of being a direct current connection, is through a capacitor connection which is formed by providing a mica ring or washer 58 that spaces the finger supporting ring 59 from the turned-in portion 54a of the outer conductor 54, this capacitor being indicated at C5 in Fig. 5. The primary purpose of this capacitor is to provide the plate-to-cathode coupling for oscillator feed-back. A grid-leak resistor is shown at 60.

The tuned anode-grid circuit comprises an inner conductor 61 and an outer conductor 62 which form a concentric line that is tuned by a capacity changing plug 63, just as described in connection with the R.-F. amplifier. The capacity that is changed by plug 63 is indicated at C6. The tuned line 61—62 is indicated in Fig. 5 as a lumped inductor 61'—62'. The coupling from the oscillator to the first detector is through a window or opening 65 in the outer conductor 62 as will be explained below. A cover or casing 67 may be provided for the R.-F. amplifier, the oscillator and the detector portions of the unit.

Referring now to the detector or converter tube 12 and to the method of coupling into it, a box-like compartment 68 of conducting material bridges the outer conductors 47 and 62 of the R.-F. amplifier and oscillator plate circuits, respectively. The detector tube 12 is set into the compartment 68 in inverted position in this particular example as shown more clearly in Figs. 2 and 3, the view in Fig. 3 being taken at right angles to the one in Fig. 2.

The compartment 68 comprises end portions *m* and *n* and top and bottom portions *o* and *p*, respectively. The sides of the compartment 68 are formed by the surface portions of the plate circuit conductors 47 and 62 containing the narrow vertical slit-like opening 52 and the horizontal rectangular opening 66, respectively.

The connections to the three electrodes of the tube 12 are made as follows: The thimble portion 19a of the anode terminal fits into a clip 71 which is supported by an insulating sheet 72 of mica or the like. Anode voltage is supplied to the clip 71 and to the anode terminal 19a through a conductor 73. As shown in Figs. 3 and 5, the anode circuit includes an intermediate frequency transformer 74. The cathode biasing connection is through a bias resistor 76 (Figs. 2 and 5).

The cathode connection for the R.-F. signal and the oscillator signal is from the top portion *o* of the compartment 68, through flexible fingers 78 (Fig. 3) to the metal shell of the tube 12, and

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through internal tube capacity (represented by capacitor C7 in Fig. 5) to the cathode of tube 12. The grid connection is through a metal tab 81 set in one corner of the compartment 68 and having flexible fingers 82 in contact with grid terminal 18.

The coupling into the grid-cathode circuit of detector tube 12 for the R.-F. signal is obtained with the above-described connections because of circulating currents induced by the presence of the window or opening 52 which causes the current to flow around the opening as indicated by the broken lines in Fig. 1a. Thus the R.-F. current has a transverse component represented by the arrow *y* which produces a potential drop between the cathode and grid connecting tabs 78 and 82, respectively. Also, there is a circulating current which flows through the tab 81 to the grid of tube 12 and through the internal grid-cathode capacity to the cathode of the upper side of conductor 47, thus producing a corresponding voltage drop along the tab 81. At these ultra high frequencies the paths traversed by the currents present inductive reactances. Therefore, the coupling from the tuned anode circuit 46—47 into the detector tube 12 may be represented as in Fig. 5 where the portion of conductor 47 along the opening 52 and common to the R.-F. amplifier and detector circuits is represented by an inductor 81' which is inductively coupled to the R.-F. amplifier plate circuit.

An adjustable arm 83 of springy material may be connected to the outer plate conductor 47 on one side of the opening 52 and positioned in capacitive relation to the grid terminal ring 18 at a point diametrically opposite the tab 81. The capacity between the arm 83 and the terminal ring 18, which is represented in Fig. 5 by capacitor C8, may be adjusted by means of a rotatable threaded rod 84 (Fig. 3) which moves a flat spring 86 and a pin 87 of insulating material in or out. The pin 87 engages the spring arm 83 to make it move in or out with the pin 87 and thus vary the value of capacity C8 for tuning the input circuit of the tube 12. In some designs it may be found that the arm 83 can just as well be omitted.

The coupling of the oscillator to the grid-cathode circuit of the detector tube may be due to the fact that the opening 66 is large enough to permit leakage of sufficient electromagnetic and electrostatic field from the tuned line 61—62 for producing sufficient coupling. It will be noted, for example, that if electromagnetic lines of force cut the tab 81, a potential difference between the grid and the cathode of tube 12 will be induced. Judging from the operation of the apparatus, however, the coupling appears to be conductive, that is, it appears to be the same kind of coupling as that between the R.-F. amplifier and the detector tube.

It has been found desirable to provide a series resonant circuit 88', 89' (Fig. 5) across the plate circuit of the tube 12, the resonant circuit being tuned to the R.-F. signal frequency. This increases the conversion efficiency and provides considerable tuning of the converter grid circuit through anode reaction. The mechanical construction for the series-resonant circuit 88'—89' is best shown in Fig. 3 where an adjustable plate portion 88 is spaced from the clip 71 by the mica sheet 72 to provide the capacity 88'. The plate portion 88 is adjustably supported by a spring arm 89 which constitutes the inductor 89'. The capacity 88' may be adjusted by means of a rotat-

able screw-threaded rod 91, the end of which acts as a stop for a lug 92 fastened to the plate portion 88.

From the foregoing description it will be apparent that I have avoided the use of coupling lines and have avoided the losses associated therewith. Among the essential features of the invention are the compartment which bridges the tuned anode circuits and which has the converter tube set therein, and the openings in the tuned anode conductors for providing the desired coupling. It should be understood that the invention is not to be limited to the theory of operation that has been given, although applicant believes that his explanation of the way in which the coupling circuits function is substantially correct.

I claim as my invention:

1. A signal mixing unit comprising two vacuum tubes each having an output circuit comprising a tuned concentric line, said tuned lines being positioned with a conductor of one line adjacent to a conductor of the other line, a compartment of conducting material bridging said adjacent conductors, a mixer tube having at least one electrode terminal positioned inside said compartment and electrically connected thereto, each of said adjacent conductors having an opening therein looking into said compartment whereby said output circuits are coupled to said mixer tube, and an output circuit for said mixer tube.

2. A signal mixing unit comprising a vacuum tube having a tuned output circuit which consists of a concentric line having an inner conductor and an outer conductor, a second vacuum tube having a tuned output circuit which consists of a concentric line having an inner conductor and an outer conductor, a compartment of conducting material bridging said outer conductors, a mixer tube having at least one electrode terminal positioned inside said compartment and electrically connected thereto, each of said outer conductors having openings therein looking into said compartment whereby said output circuits are coupled to said mixer tube, and an output circuit for said mixer tube.

3. A frequency converter unit comprising a radio-frequency amplifier having a tuned plate circuit which consists of a concentric line having an inner conductor and an outer conductor, an oscillator having a tuned output circuit which consists of a concentric line having an inner conductor and an outer conductor, a compartment of conducting material bridging said outer conductors, a detector tube having at least one electrode terminal positioned inside said compartment and electrically connected thereto, each of said outer conductors having openings therein looking into said compartment whereby said amplifier and said oscillator are coupled to said detector, and an output circuit for said detector.

4. A frequency converter unit comprising a radio-frequency amplifier having a tuned plate circuit which consists of a concentric line having an inner conductor and an outer conductor, an oscillator having a tuned output circuit which consists of a concentric line having an inner conductor and an outer conductor, said concentric

lines being substantially parallel to each other, a compartment of conducting material bridging said outer conductors, a detector tube having at least one electrode terminal positioned inside said compartment and electrically connected thereto, said detector tube being positioned with its longitudinal axis at right angles to the longitudinal axis of said concentric lines, each of said outer conductors having openings therein looking into said compartment whereby said amplifier and said oscillator are coupled to said detector, and an output circuit for said detector.

5. A frequency converter unit comprising a radio-frequency amplifier having a tuned plate circuit which consists of a concentric line having an inner conductor and an outer conductor, an oscillator having a tuned output circuit which consists of a concentric line having an inner conductor and an outer conductor, a compartment of conducting material bridging said outer conductors, a detector tube having an input circuit including input electrodes and having at least one input electrode terminal positioned inside said compartment, each of said outer conductors having openings therein looking into said compartment to couple said amplifier and said oscillator to said detector, a portion of one of said outer conductors adjacent to the opening therein being common to said detector input circuit and to the tuned circuit in which said last conductor is included, and an output circuit for said detector.

6. A frequency converter unit comprising a radio-frequency amplifier having a tuned plate circuit which consists of a concentric line having an inner conductor and an outer conductor, an oscillator having a tuned output circuit which consists of a concentric line having an inner conductor and an outer conductor, said concentric lines being substantially parallel to each other, a compartment of conducting material bridging said outer conductors, a detector tube having an input circuit including input electrodes and having at least one input electrode terminal positioned inside said compartment, said detector tube being positioned with its longitudinal axis substantially perpendicular to the plane of said concentric lines, each of said outer conductors having openings therein looking into said compartment to couple said amplifier and said oscillator to said detector, a portion of one of said outer conductors adjacent to the opening therein being common to said detector input circuit and to the tuned circuit in which said last conductor is included, and an output circuit for said detector.

ALFRED H. TURNER.

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The following references are of record in the file of this patent:

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