

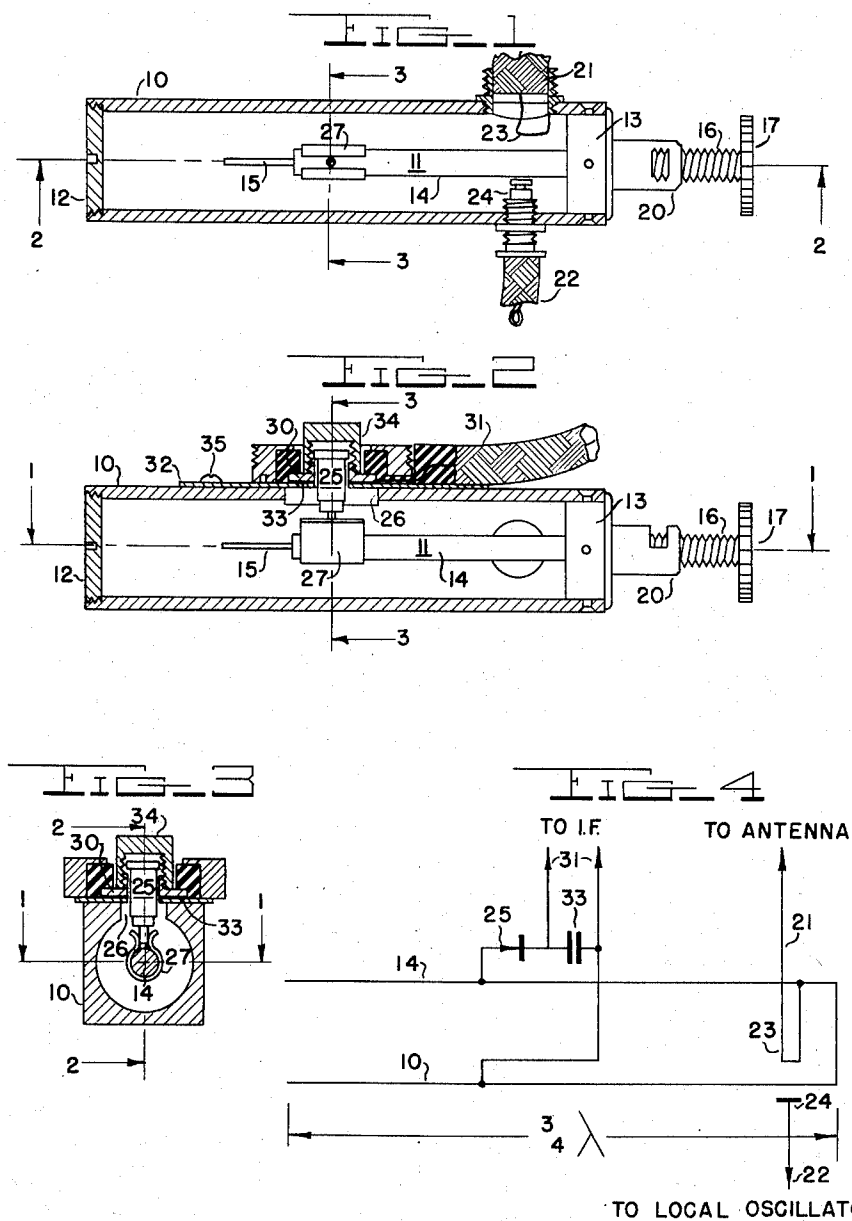
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IMPEDANCE MATCHED FREQUENCY CONVERTER

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IMPEDANCE MATCHED FREQUENCY
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This invention relates to transmission-line sections and particularly to a transmission-line section into which may be coupled two independent sources of electrical energy and from which electrical energy may be derived from a point on the section matching the impedance of the energy deriving means.

In heterodyning, or mixing, two separate sources of energy and deriving therefrom a single output energy, it is often desirable that maximum transfer of energy take place between the several energy transmitting means comprising the heterodyning system. To effect this result, it is necessary that the impedances of the means which feed, and the means which derives, energy from the heterodyning device match the impedance of the heterodyning device at the respective points of application thereto.

Therefore an object of this invention is to produce a heterodyning device in which maximum transfer of energy is provided by impedance matching.

Another object of the invention is to produce a heterodyning device to which energy may be applied and from which energy may be derived at a point thereon such that the impedance of the energy-deriving means is matched to that of the device.

Another object of the invention is to produce, in the form of a transmission-line section, a heterodyning device from which heterodyned energy may be removed at a point matching the impedance of the energy-removing means.

A further object of the invention is to create a heterodyning device, in the form of a transmission-line section, to which energy may be applied at a point on the section matching the impedance of the energy-applying means and from which energy may be derived at a point on the section matching the impedance of the energy-deriving means.

With these objects in mind, the present invention will now be described as comprising a resonant transmission-line section having the property that the impedance looking into the line section varies along its length. Into the transmission line section is coupled a first source of energy from a receiving antenna. This coupling is made at a point on the line section such that the impedance of the section at that point matches the impedance of the antenna energy coupling means. Energy from a local oscillator is also coupled to the line. The two energies thus applied to the line are heterodyned to produce a beat. Energy of the beat frequency is derived

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from the section by a detecting means coupled thereto at a point matching the impedance of the detecting means, thereby providing maximum energy transfer from the line section to the detecting means.

A transmission-line section in the form of a resonant transmission line, equal in length to an odd number of quarter wave lengths at the frequency of the energy within the line, presents an impedance looking into the line at any point which varies as a $\sin^2$ relation along the line, as will be more fully explained hereinafter. By constructing the transmission-line section short circuited at one end and open circuited at the other end, and equal in length to three-quarters wavelength ($\frac{3}{4}\lambda$) of the energy coupled into the line, the impedance looking into the section will be a minimum (zero) at the short-circuited end of the line, will rise to a maximum, depending on the Q of the line, at a point one-quarter wavelength ($\frac{1}{4}\lambda$) away from the short-circuited end, and will drop to a minimum (almost zero) at a point one-half wavelength ($\frac{1}{2}\lambda$) away from the short-circuited end of the transmission-line section.

This property of a three quarter wavelength transmission-line section, short-circuited at one end and open circuited at the other, is made use of in the present invention in the following manner. In the vicinity of the short-circuited end of the line, energy from a receiving antenna is applied inductively as by loop coupling. Since in this region the line-section impedance is low, impedance matching between the section and the transmission line carrying energy from the antenna may be readily accomplished, as by varying the coupling between the loop and the section. Into the line is also coupled a source of energy from a local oscillator tuned approximately to the frequency of the incoming antenna energy. There is thus produced the conventional intermediate frequency beat. A standing wave of energy thus exists on the transmission-line section, which is tuned to an electrical length of three-quarters wavelength ($\frac{3}{4}\lambda$) at the frequency of the incoming antenna energy.

As explained hereinbefore, in the region one-half wavelength away from the short-circuited end of the transmission line section, the impedance of the section will be of very low magnitude. In this region the detecting means is connected between transmission-line conductors, the exact point being chosen in accordance with the impedance of the detecting means.

A particular embodiment of the heterodyning

device of this invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 shows a sectionalized plan view taken along line 1—1 of Figs. 2 and 3;

Fig. 2 shows a sectionalized elevation taken along line 2—2 of Figs. 1 and 3;

Fig. 3 shows a cross section of the transmission-line section taken along line 3—3 of Figs. 1 and 2; and

Fig. 4 shows a schematic diagram depicting the equivalent circuit of the transmission-line section.

Referring to the drawings, the transmission-line section is shown in the form of a coaxial transmission line having an outer conductor 10 and an inner conductor 11. Conductor 10 is closed at one end thereof by a wall 12 and at the other end thereof by a cylindrical plug 13. Plug 13 also constitutes a short-circuiting member for one end of the line section, supporting a portion 14 of the inner conductor 11. Portion 15 of inner conductor 11 is movable axially within portion 14 of inner conductor 11, and extends therethrough into the chamber formed by outer conductor 10 and wall 12. At the other end portion 15 extends exteriorly of the outer conductor 10 and terminates in a threaded member 16 having a knurled tuning knob 17. A boss 20, integral with plug 13 and portion 14 of inner conductor 11, is threaded internally to receive threaded member 16. It will be readily seen that rotation of knob 17 will shorten or lengthen the transmission line, comprised of conductors 10 and 11, by virtue of the axial movement of portion 15 of inner conductor 11 thereby produced. In the particular embodiment under description, the distance between the short-circuited end of the transmission-line section at plug 13 and the open-circuited end of the line section at the end of inner conductor 11 is made approximately equal to three-quarters wavelength ($\frac{3}{4}\lambda$) at the operating frequency of the section.

Into the transmission-line section thus described and shown schematically in Fig. 4 are coupled two sources of energy from coaxial transmission lines 21 and 22, respectively. Transmission line 21 carries received energy from an antenna and is terminated in a coupling loop 23. Transmission line 22 is terminated in a conducting button 24 forming capacitive coupling between transmission line 22 and inner conductor 11. In order to minimize direct coupling between these two sources of energy, line 22 is disposed on the opposite side of conductor 11 from line 21.

In this manner two sources of energy of approximately the same frequency may be heterodyned within the transmission-line section.

At a point approximately one-half wavelength ($\frac{1}{2}\lambda$) away from the short-circuited end of the transmission-line section, a detecting means is connected between the inner and outer conductors. In the present embodiment, the detecting means comprises a crystal contained within crystal holder 25. Crystal holder 25 is inserted into the space between conductors 10 and 11 through an opening 26 in outer conductor 10. Contact between the crystal and inner conductor 11 is made through spring clips 27 attached to portion 14 of inner conductor 11. The other terminal of the crystal is connected to a conducting member 30 which is in turn connected to the inner conductor of a coaxial trans-

mission line 31. Conducting member 30 is separated from plate 32, bearing the entire crystal assembly, by an annular mica insulator 33 which forms a capacitive connection between outer conductor 10 and the inner conductor of transmission line 31. A cap 34 permits insertion and removal of crystal holder 25. Screws 35 anchored in outer conductor 10 extend through axially elongated slots in plate 32, thereby providing limited axial adjustment of crystal holder 25 with respect to spring clip 27. This permits adjustment in the impedance point at which the crystal in holder 25 derives energy from the transmission-line section.

The beat frequency existing by virtue of the heterodyning of energy from transmission lines 21 and 22 is rectified in the crystal of holder 25 and the intermediate frequency component of the derived energy is transmitted through line 31 to a conventional intermediate frequency amplifier. The high frequency components of the energy are by-passed through the condenser formed by annular dielectric member 33 and do not reach the IF amplifier.

The input impedance to the transmission-line section thus described will vary as a sine² function, as will be particularly described below. The impedance at any point along the line is given approximately by the following relation:

$$Z = \frac{4Q|Z_0|}{3\pi} \sin^2 \frac{2\pi x}{\lambda}$$

Z = input impedance at any point along the line.

$$Q = \frac{2\pi fL}{R}$$

f = frequency of energy applied to transmission-line section.

L = inductance per unit length of the transmission line.

R = resistance per unit length of the transmission line.

Z_0 = characteristic impedance of the transmission-line section.

x = distance in wavelengths between point under consideration and short-circuited end of transmission-line section.

λ = wavelength of energy applied to transmission-line section.

The relationship above indicates that the input impedance along the line becomes zero at the short-circuited end of the line and at each half wavelength ($\frac{1}{2}\lambda$) away therefrom; and becomes a maximum at every odd quarter wavelength ($\frac{1}{4}\lambda$, $\frac{3}{4}\lambda$ etc.) away from the short-circuited end of the transmission-line section. It will be noted further that this impedance is purely resistive. The formula given above is very accurate for high values of Q . The formula is least accurate in the region where x equals an odd half wavelength ($\frac{1}{2}\lambda$), but even in this region the deviation from the value of Z as calculated from the above formula is very slight. In a particular embodiment a transmission-line section was constructed having a Q of approximately 100 and a characteristic impedance, Z_0 , of approximately 80 ohms. With these parameters, the impedance at a distance one-half wavelength away from the shorted end of the transmission line, i. e., where

$$x \text{ equals } \frac{\lambda}{2}$$

was calculated to be 0.4 ohm at a phase angle of .005 radians. It will be understood that the above values as calculated are only approximate, inasmuch as the end effect of wall 12 and other minor factors have been neglected. It will thus be seen that even at the point of greatest in-

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accuracy the formula given above is very close to the actual conditions encountered. In the transmission-line section actually constructed the detecting crystal in holder 25 had an impedance of approximately 200 ohms. Therefore, in order to match the impedance of the crystal to that of the line it was merely necessary to slide the crystal holder 25 along the line within spring clip 21, a distance equal to $.04\lambda$ away from the half-wave point.

In like manner, maximum energy transfer from the antenna to the transmission-line section may be obtained by applying antenna line 21 to the line section at a low impedance point and making final adjustment in coupling by rotation of coupling loop 23. No attempt is generally made to match the impedance of transmission line 22 to that of the transmission-line section, inasmuch as a great deal of energy is available from the local oscillator, and no effort need be made to conserve it. However, in the case of antenna energy in transmission line 21 and energy derived from the transmission-line section by the detecting means, it is important that the impedances be closely matched in order that maximum transfer of energy may take place. For the embodiment illustrated, the coupling of the detecting means to the transmission-line section is made direct, and the impedance relationship between that of the crystal and that of the line section is in a one-to-one ratio. However, the point of application of transmission line 21 to the transmission-line section need not necessarily be that point at which the impedance of the transmission line 21 matches the impedance of the transmission-line section. This is because of the impedance transformation taking place in the inductive coupling between the transmission-line section and the coupling loop 23. In order to attain optimum impedance matching between transmission line 21 and the transmission-line section, it is simply necessary to rotate coupling loop 23 thereby varying the coupling and hence the impedance transformation ratio.

While the specific embodiment shown and described herein, illustrates the antenna coupling as being of the inductive type, the local oscillator as being of the capacitive type, and the detector coupling as being of the conductive type, it is obvious that for most purposes these three types are interchangeable. Accordingly, it will be understood that the invention is not limited to a particular type of coupling for any particular purpose.

It will be readily apparent that the transmission-line section need not be necessarily three-quarters wavelength long so long as a resonant transmission line is used which will produce the impedance relation given by the approximate formula stated hereinbefore.

It is to be understood that the embodiment of

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this invention described above is exemplary only; and the scope thereof is not to be limited to this description, but will be pointed out more particularly in the appended claims.

5 The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

10 What is claimed is:

1. In a device for heterodyning energy, a coaxial transmission line section having an inner and an outer conductor, means for adjusting the length of the inner conductor, coaxial line and coupling loop means for applying energy to said section from one side thereof, the coupling loop being rotatable for impedance matching, coaxial line and capacitive coupling means for applying energy to said section on the opposite side of said section from said coaxial line and coupling loop means, and a non-linear impedance member connected between the inner and outer conductors of said section at a point on said section having an impedance that matches the impedance of said member.

2. In a device for heterodyning energy, a coaxial transmission line section having an outer conductor shorted at one end and having an inner conductor extending into the outer conductor a distance of $\frac{3}{4}$ wavelength from the shorted end, coaxial line and coupling loop means for applying energy to said section from one side thereof near the shorted end, the coupling loop being rotatable for impedance matching, coaxial line and capacitive coupling means for applying energy to said section on the opposite side of said section from said coaxial line and coupling loop means, and a crystal rectifier connected between the inner and outer conductors of said section at a point $\frac{1}{2}$ wavelength from the shorted end thereof.

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