March 2, 1948. W. M. SHARPLESS 2,436,830

TRANSMISSION SYSTEM AND METHOD

Filed April 19, 1943 3 Sheets-Sheet 1

FIG. 1

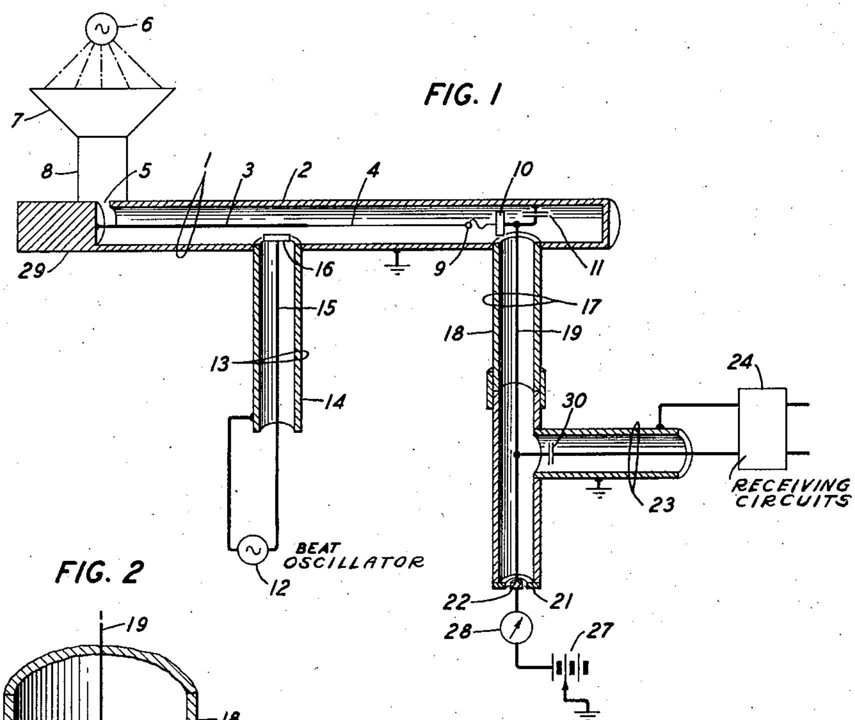


FIG. 2

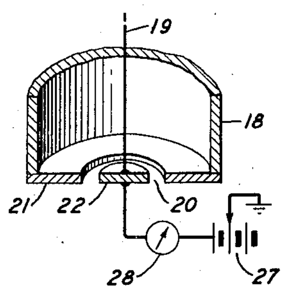


FIG. 6

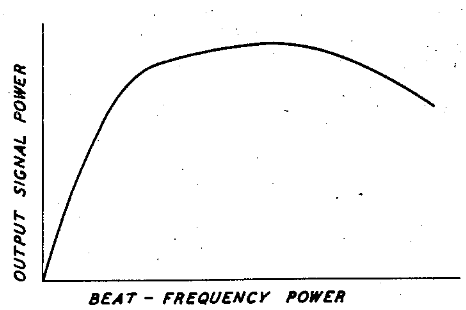
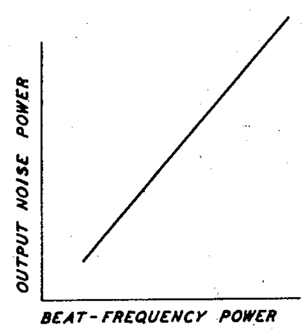


FIG. 7



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TRANSMISSION SYSTEM AND METHOD

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FIG. 11

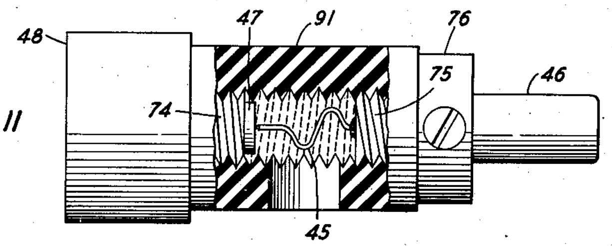


FIG. 4

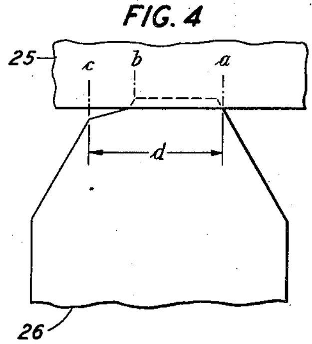


FIG. 5

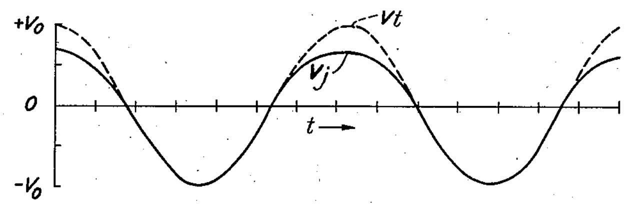


FIG. 3

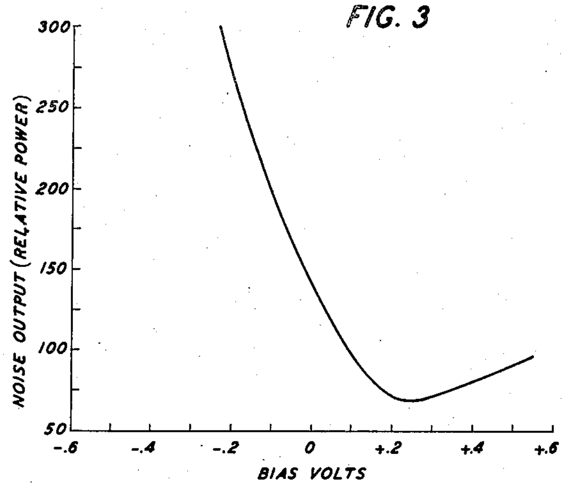
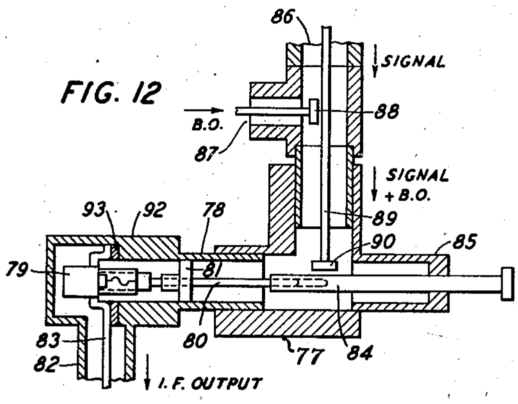


FIG. 12



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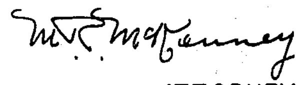

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TRANSMISSION SYSTEM AND METHOD

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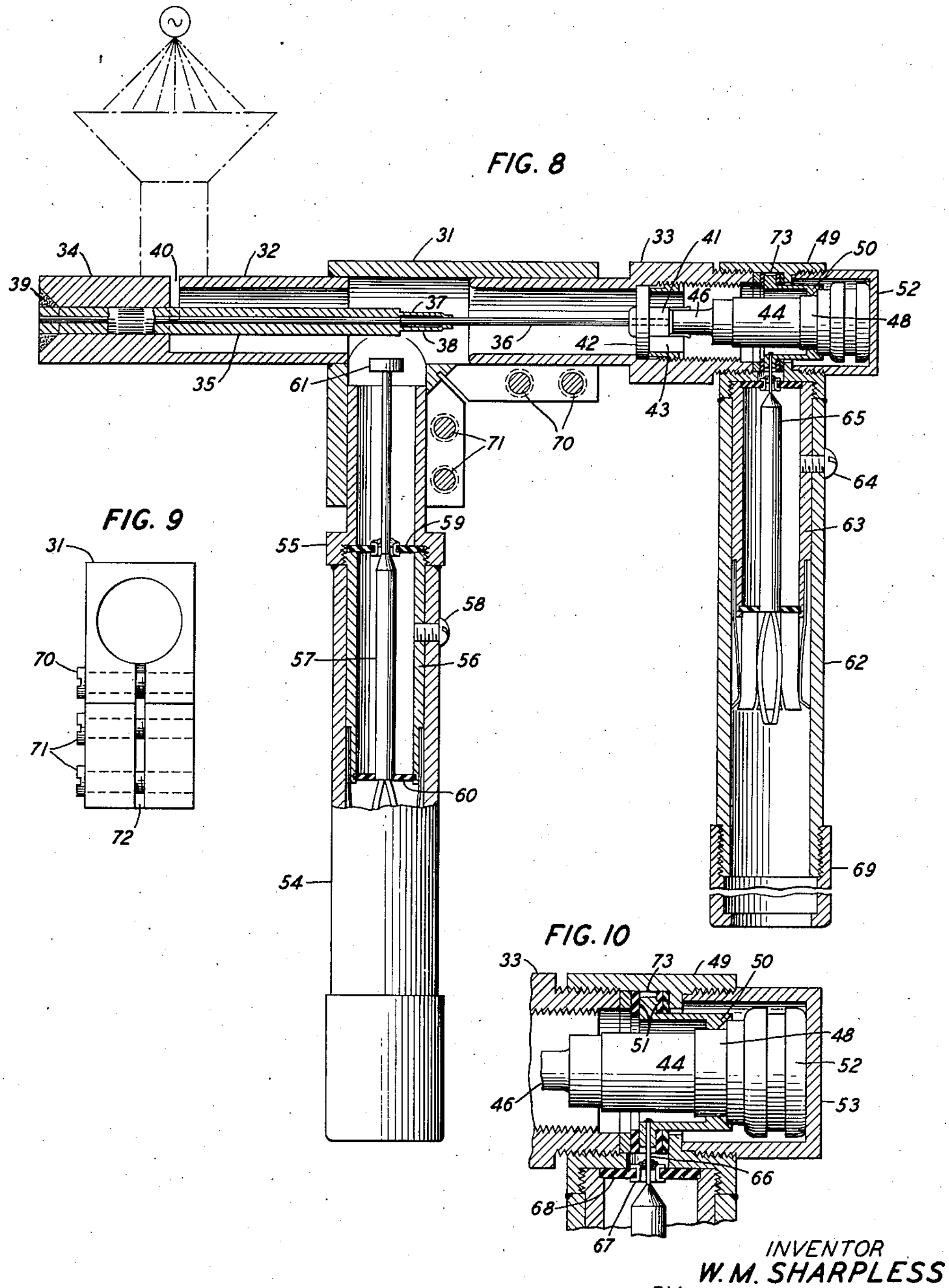

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Patented Mar. 2, 1948 2,436,830

UNITED STATES PATENT OFFICE

2,436,830

TRANSMISSION SYSTEM AND METHOD

William M. Sharpless, Fair Haven, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 19, 1943, Serial No. 483,607

7 Claims. (Cl. 250—20)

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This invention relates to transmission systems, apparatus, and methods and particularly to those concerning the conversion of transmission energy from one frequency to another.

Objects of the invention are to effect a substantial reduction in the noise energy resulting from the conversion process; to obtain a more favorable relation between the signal and noise energy in the output circuits; to increase the efficiency of the translating elements used in conversion and other systems; to improve the structure of conversion apparatus, and in other respects to effect improvements in systems and apparatus of this general character.

In conversion systems for wave energy in the ultra-high frequency range it is the practice to use a rectifying device of the crystal type for translating the high-frequency waves into waves of some convenient intermediate frequency. This device consists of a crystal element of some suitable material, such as silicon, and a fine wire arranged to make a point-contact with the crystal surface. Although manufactured under uniform conditions, it is found that substantial numbers of these rectifier units when used in conversion systems, and particularly for converting microwaves (order of 10 centimeters), are productive of noise currents in the output circuits. It is believed that these objectionable noise currents are caused by the presence of parasitic voltages present at or near the rectifying surface of the crystal which are probably the result of variations in the small contact area between the contact wire and the crystal surface.

With these considerations in mind applicant has discovered that these noise currents substantially disappear from the output circuits of the converter if a small direct voltage of the proper magnitude and polarity is applied to the terminals of the rectifier unit. He has also discovered that this controlling voltage is quite critical with respect to polarity and magnitude. More specifically in a converter of the kind above discussed employing rectifiers with silicon crystals the controlling potential applied to the crystal should be positive and should have a critical value which was found to be a fractional part of a volt. If the polarity is negative, the noise current increases and the signal output decreases for all values of controlling potential applied to the crystal. The signal output may be restored by an increase in the beating oscillator supply, but the increased noise currents remain. On the other hand if the applied positive potential is increased or decreased from its critical value, the result in

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either case is a progressive increase in the noise current. Any effort, therefore, to improve the relation between signal and noise by resorting to the usual methods of applying bias voltage of sufficient magnitude to increase the signal output is generally unproductive of satisfactory results in these microwave converter systems. If a positive bias voltage large enough to affect the signal appreciably is applied to the rectifier, the disproportionate increase in the noise current results in an impairment rather than an improvement in the signal-noise relation. Yet by taking advantage of applicant's discovery and applying a small direct positive controlling potential of critical value to the rectifier crystal it is possible to substantially eliminate the noise currents without producing any adverse effect on the signal currents.

It is also a characteristic of these frequency conversion systems that the output signal energy of intermediate frequency increases proportionately, in response to increasing energy supplied to the system by the beat-frequency source, until a given value is reached beyond which further increase in the beat-frequency energy does not cause any appreciable gain in the output signal. Also it is a further characteristic of these systems that the noise currents present in the output circuits increase in proportion to the increase of energy supplied by the beat-frequency source.

Another feature of the invention, therefore, is the method of operating a conversion system for optimum results which consists in effecting an increase in the output signal by increasing the beat-frequency energy supplied to the input of the system until a value is reached beyond which any further increase does not produce a corresponding increase in the signal, and applying to the rectifying element of the system a direct controlling voltage of given polarity and of a magnitude sufficient to minimize the presence of noise currents in the output circuit but insufficient to affect said output signal adversely. This method makes it possible to take advantage of the fact that a direct voltage of critical value, too small to have an adverse effect on the signal, when applied to the rectifier is nevertheless capable of effecting a large reduction in the noise currents which accompany increased signal power, and which would otherwise either have to be tolerated or reduced at the expense of signal power.

Another feature of the invention is a converter structure of hollow and concentric conducting elements comprising inlet sections for the high-frequency signaling and beat-frequency waves, a main line or converting section with which said inlet sections communicate, said converting section having a fixture in one end thereof for the insertion and easy replacement of the rectifying element, an outlet section communicating with said converting section and having an outlet for the intermediate frequency waves, the length of said outlet section bearing a definite relation to the wave-length of said intermediate frequency waves, by-passing means at the junction of the said converting and outlet sections to prevent the appearance of said high-frequency waves in the outlet section, and by-passing means at the end of said outlet section for enabling the application of a direct voltage across the terminals of the rectifying element.

Another feature of the invention is a converter in which the central conductor of the main line is made in sections of two different sizes to present an impedance to the rectifying element for the purpose of enhancing the production of harmonics of the beat-frequency wave, and in which the character of the reactance of the main line is chosen to obtain the desired phase relation between the fundamental and harmonic waves by selecting the proper ratio between the lengths of the sections of the inner conductor and the lump loading along the sections. The advantage of this feature is that the harmonic waves may be utilized to control the shape and amplitude of the resultant wave in such a manner that a gain is realized in the relation between signal and noise output power.

The foregoing and other features of the invention will be discussed more fully in the following detailed specification.

In the drawings accompanying the specification:

Fig. 1 is a conventional illustration of the converter system;

Fig. 2 is a detail of the converter;

Fig. 3 is a curve showing the relation between noise output power and direct voltage applied to the terminals of the rectifier;

Fig. 4 is an enlarged view of the crystal rectifier contact point;

Fig. 5 is a curve illustrating the effect of applied direct controlling voltage on the alternating voltage of the contact at the terminals of the rectifier;

Fig. 6 is a curve illustrating the effect of beat-frequency power on the output signal;

Fig. 7 is a curve illustrating the effect of beat-frequency power on the noise power in the output circuit;

Fig. 8 is an assembly view partly in cross section showing the details of the converter structure;

Figs. 9 and 10 are detail views, Fig. 10 being considerably enlarged to illustrate the parts more clearly;

Fig. 11 is an enlarged view of the rectifier unit; and

Fig. 12 is an alternative structure in which the main line is capable of being tuned.

The converters disclosed herein are frequently used in the first detection stage of microwave receivers of the high-gain type. It is therefore very important to achieve as high a value as possible for the ratio of signal-to-noise power in the output circuit of the rectifying element. Accordingly the structural and circuit features of the converters disclosed herein are designed with the purpose in view of improving this ratio by minimizing the noise power which normally occurs in the output circuit of the rectifier and at the same time by increasing the signal power in said output circuit.

Referring to the drawings, Fig. 1 discloses a conversion system of the general type to which the features of this invention are applicable. It comprises a main line or converting section 1, including a hollow external conductor 2 and an internal concentric conductor 3—4. The concentric conductor 3—4 is connected electrically to the solid plug 29 in which the hollow conductor 2 terminates, thus forming a short circuit between these conductors at that end of the line. Also at this end of the line an aperture 5 is cut in the hollow conductor 2 in order that the high-frequency signal waves may be admitted and impressed upon the inner conductor 3—4. These high-frequency signal waves, which are radiated from a source 6, are collected by a suitable receiving horn 7 and guided through an input chamber 8 to the aperture 5.

The central conductor 3—4 is connected at the other end of the main line 1 to the spring contact 9 of a crystal receiver, and the crystal element 10 thereof is connected through a high-frequency by-pass condenser 11 to the outer conductor 2. The capacitance of the condenser 11 is such that it offers a relatively low impedance to the high-frequency signal and beating waves and a relatively high impedance to the resulting waves of intermediate frequency. Thus the circuit comprising the central conductor 3—4, the outer conductor 2 and the condenser 11 serves to confine the high-frequency currents to the main line of the converter.

The waves from the beating oscillator 12 are applied to the converting or main line section through the input section 13, which comprises the outer hollow conductor 14 and the inner concentric conductor 15. The inner conductor 15 terminates in a probe 16 by means of which the coupling of the beating oscillator to the system may be controlled.

The outlet section 17 for the intermediate frequency waves is joined to the main line 1 near the rectifier end thereof. It comprises the hollow conductor 18 and concentric conductor 19 which are electrically connected respectively to the hollow conductor and to the concentric conductor of the main line. The lower end of the intermediate frequency section 17 is constructed to form a condenser between the central and outer conductors. This construction is seen more clearly in Fig. 2, the condenser being formed by the dielectric space 20 between the concentric metallic ring 21 and the inner concentric metallic disc 22 and serving to present a relatively low capacity to the intermediate frequency waves. The purpose of this condenser 20 will be explained more fully hereinafter. The intermediate frequency waves are taken from the line 17 by means of an auxiliary or stub line 23 which terminates in the succeeding circuit 24 of the receiving system.

Since the noise produced by the crystal rectifiers in these microwave converters is a limiting factor in the gain that can be derived from the receiver as a whole, much study has been made with a view to determining the causes and to discover, if possible, some means for minimizing the detrimental noise currents appearing in the output circuit of the rectifier. Actual experiments conducted as a part of this general study have clearly demonstrated that the use of the conventional negative direct bias voltages on the rectifying element afford no improvement whatever in the signal-noise relation. As a matter of fact the application of these conventional bias voltages were found to be distinctly detrimental. For example, the application of the usual negative direct biasing voltage to these crystal rectifiers results in a large increase in the noise power and a substantial decrease in the signal power. Also the use of direct biasing voltages of those magnitudes which are customarily employed in the art for biasing detectors and like devices was found to increase rather than to minimize the noise power. And while it was possible, as before noted, to restore the signal power by increasing the beat-frequency supply, this expedient was always productive of an increase in the noise power. Notwithstanding the adverse results of these experiments, which indicated that no improvement could be expected from the use of biasing voltages, applicant discovered on further experimentation that when a direct voltage of critical value is applied to the crystal rectifier unit the noise power in the output circuit of the converter is substantially eliminated. And contrary to what would be expected from past experience, it was found that this critical voltage is positive in polarity and very small in magnitude, too small in fact to have any appreciable effect on the signal power in the output circuit of the rectifier. The location of this critical voltage is shown on the characteristic curve of Fig. 3, which is plotted between noise output power and bias volts. An examination of this characteristic curve shows that the noise power rises very rapidly with the application of increased values of negative voltage and that a similar result occurs when a positive voltage of any substantial value is applied to the rectifier unit. However, there is one critical value (usually between .20 and .40 volt positive) which has the effect of substantially eliminating the presence of noise power in the output circuit.

It is believed that the critical effect of this biasing voltage will be understood more clearly from a consideration of the nature of the converter contact. The rectifier unit illustrated in Fig. 4, many times enlarged, comprises a crystal **25** of silicon and a fine spring wire **26** making a point contact with the surface of the crystal. The spring wire **26**, which is only about .005 inch in diameter, is ground to a sharp point and brought into contact at the desired pressure with the surface of the crystal. The unit is then tapped gently to upset or blunt the pointed end of the wire to form a contact area of finite dimensions. This area, if perfectly formed, constitutes a circle having the diameter *d*, the entire area of the circle making intimate contact with the surface of the crystal **25**. In practice, however, these contact areas are often imperfectly formed, and it may be assumed that the region from *a* to *b* represents the area of intimate contact between the wire and the surface of the crystal and that the area from *b* to *c* represents a separating gap which may contain air or some other insulator. According to the theory of contact rectifiers a space charge is produced in the crystal which acts as a potential barrier and accounts for the rectifying properties of the contact. The boundary of this potential barrier is schematically illustrated in Fig. 4 by the dotted line. Assume now that the voltage drop to be expected across a gap, such as that shown in the figure, is represented by the character V_j. At very low forward voltages

and all reverse voltages V_j will be nearly equal to the voltage V_t at the terminals of the rectifier. As the forward voltage is increased, however, an appreciable current will begin to flow, and part of the applied voltage will lie across the crystal outside the potential barrier. It follows then that when a sinusoidal voltage such as

$$V_t = V_0 \text{ cosine } 2\pi f T$$

is impressed across the rectifier the resulting junction voltage V_j will have the form illustrated in Fig. 5, decidedly non-sinusoidal. The negative peak of the voltage wave across the gap in Fig. 4 will be considerably greater than the positive peak.

If now a positive direct potential of the critical value above discussed is applied to the crystal **25**, with respect to the contact wire **26**, the negative peak of the wave is reduced and the positive peak is increased by amounts which equalize the magnitudes of these peaks. The effect therefore of the applied critical direct voltage is to compensate for the irregularity in the wave of the applied voltage resulting from the imperfections in the contact surface of the rectifier. It has been established quite clearly that the noise currents produced by these rectifiers are correlated with these contact imperfections. The minute and delicate character of these units makes it difficult to eliminate these imperfections in the manufacturing process and to guard against their occurrence as a result of shock subsequent to manufacture. The discovery that a small controlling direct voltage will tend to overcome the noise resulting from imperfections in manufacture when these units are used in microwave converters has the important advantage that it permits the use of many units which would otherwise be discarded.

A further advantage realized from the use of the proper value of the controlling direct voltage on the crystal units is that it permits a substantial increase in the signal output power without undue noise. Referring to Fig. 6 it will be noted that the power of the signal in the output circuit of the rectifier increases rather sharply with an increase in the beat-frequency power until a definite value of beat-frequency power is reached beyond which further increases do not yield any substantial increase in the signal power. However, this simple method of increasing the signal power has the disadvantage of correspondingly increasing the noise power. Fig. 7 indicates this relation between beat-frequency power and noise power. The relations indicated in Figs. 6 and 7 are in general those characterizing a crystal converter in which no direct controlling voltage is applied to the rectifying unit. The improvement in signal power and the freedom from signal variation to be realized by an increase in the beat-frequency power beyond the knee of the curve in Fig. 6 are much to be desired. However, it has only been possible heretofore to take advantage of this relation by accepting an undesirable amount of noise power. Having discovered, however, that a small critical value of controlling direct voltage, too small to have any appreciable effect on the signal power, serves to reduce materially the output noise, it is now possible to effect a marked reduction in the conversion loss and to operate the system at a much higher efficiency. More specifically, the power supplied from the beat-frequency oscillator is increased until the output signal power approaches its maximum value, and the predetermined critical value of positive potential is applied from battery to the crystal of the rectifying unit to eliminate substantially the noise power which would otherwise appear in the intermediate frequency line. The controlling voltage for the crystal rectifier is applied by connecting the battery 27 to the condenser element at the extreme end of the intermediate frequency line 17. By choosing the proper value for the capacity of the condenser 21—22, it is possible to establish at this end of the line an effective short circuit at the intermediate frequency. If then the length of the line 17 is chosen at an odd multiple of one quarter of the wave-length of the intermediate frequency, a nodal point in the voltage wave occurs at the disc 22. The battery 27 may now be connected at this nodal point without interference with the system, and the circuit for applying the battery voltage to the elements of the rectifier may be traced from the positive pole of the battery through the measuring instrument 28, disc 22, central conductor 19, crystal 10, contact wire 9, central conductor 3, outer conductor 2 to ground and thence to the opposite pole of battery 27.

In addition to the foregoing advantages, applicant has also discovered that an improvement in signal power may be realized by a novel structural design of the central conductor in the main line of the converter. As illustrated in Fig. 1 this central conductor is made in two sections, the left-hand section 3 having a larger diameter than the right-hand section 4. Because of this difference in diameters, the central conductor presents an impedance to the rectifier which causes the rectifier to support and thus produce harmonics, notably the second harmonic of the beat-frequency wave. By choosing a proper ratio between the length of the section 3 and the length of section 4 the line loading reactance of the line may be controlled in such a manner as to bring the harmonics into the desired phase relation with the fundamental wave. More specifically, by controlling the phase in such a way that the maximum amplitudes of the second harmonic wave are made to coincide with the corresponding amplitudes of the fundamental wave a peaking effect is obtained which results in a substantial improvement of signal power in the output circuits. It should also be noted that other design factors in the converter structure, particularly those involving discontinuities, such as the ceramic elements which support and insulate the conductors, may be employed for securing the desired phase relationship. The ceramic elements constitute a discontinuity in the capacity and, if properly located, can be used to control the phase relation.

The operation of the converter will now be explained briefly. The incoming signal wave, which may have a frequency in the neighborhood of 3,000 megacycles, is received by the pick-up horn 7 and guided through the inlet chamber 8 and aperture 5 where it is impressed upon the central conductor 3—4. At the same time the beat-frequency wave supplied by a suitable oscillator 12 is applied through the input section 13 to the main line 2. The frequency of the beating wave is chosen with respect to that of the signal wave to give the desired intermediate frequency. The signal and beating waves are applied to the rectifier 9—10, which serves to convert the modulated signal wave into a modulated wave of the intermediate frequency. Currents of the signal and beating frequency flowing in the output circuit of the rectifier are by-passed by the condenser 11 and are thus confined to the main line 2. The condenser 11, however, offers a high impedance to the intermediate frequency currents, and these currents are thus confined to the outlets 17 and 23 over which they are applied to the receiving circuit 24, which may be an intermediate frequency amplifier. While the converter is thus in operation a direct voltage of the predetermined critical value is applied from battery 27 through the meter 28 and across the terminals of the rectifying crystal 10. Current from the battery 27 is prevented from flowing into the outlet section 23 by means of the condenser 30 which offers a low impedance to the intermediate frequency waves. As above explained, the condenser 22 located in the end of the intermediate frequency line 17 serves as an effective short circuit across the line 17 to prevent current of the intermediate frequency from entering the battery circuit.

Referring now to Figs. 8, 9, 10 and 11, a description will be given of the structural details of one form of converter in which the features of this invention may be incorporated. The main line of the converter, which is arranged horizontally in the drawing, consists of a number of parts assembled to form a high-frequency circuit of inner and outer concentric conductors and includes a rectifying element for translating the high-frequency waves. The block or frame 31, which serves as a supporting element for other parts of the structure, contains a horizontal bore therethrough for receiving the shell 32 in one end and the hollow coupling 33 in the other end. The shell 32 terminates in a solid block 34 containing a central bore into which the holder 35 is tightly fitted. The holder 35 in turn contains a longitudinal bore of smaller diameter through which the concentrically located pin 36 extends. The holder 35 is knurled to insure a tight fit in the block 34, and the central rod 36 is held firmly in place in the holder by means of the spring tips 37 and 38. As an additional means for securing the assembled holder and rod in position, the end of the block 34 is countersunk to receive a quantity of binding solder 39. A saw slot 40 at the juncture of the shell 32 and the integral block 34 provides an aperture through which the high-frequency signal waves are admitted.

The other end of the central rod 36 is supported in a chuck assembly comprising the metallic chuck 41 and the ceramic insulating disc 42. The disc 42, to which the metallic chuck 41 is secured in any suitable manner, rests against a shoulder in the hollow coupling 33 and is held firmly in place by a threaded sleeve 43 which screws into the tapped bore in the end of the coupling. A small drill hole in the chuck 41 receives the end of the rod 36 where it may be soldered to form a good electrical connection.

The purpose of the chuck 41 is to provide a flexible jack connector for the rectifier unit 44. The details of this unit are disclosed in Fig. 11 and will be described later. For the moment, however, it is sufficient to note that the spring contact wire 45 of the rectifier is electrically connected to the plug 46 and that the crystal element 47 is electrically connected to the metallic base 48. The unit 44 is housed within and supported by the coupling block 49. The right-hand end of the coupling 33 is externally threaded for engagement with the internally threaded portion of the block 49 thus securing the block 49 to the remainder of the main line structure.

The rectifier unit 44 is supported within the block 49 by means of a chuck 50 having a number of saw slots therein to give it the necessary resilience for gripping the metallic base 48 of the rectifier unit. The chuck 50 is insulated from the block 49 and from the other outer metallic parts of the structure by means of mica washers 51 and is held firmly in position between these washers by means of the pressure exerted thereon when the coupling 33 is screwed into position. The metallic base of the rectifier unit 44 is covered by a rubber grommet 52 and the open end of the structure is sealed by a threaded cap 53.

The input line for the beat-frequency source consists of an assembly including the outer shell 54, an adapter 55, an inner shell 56 and the central conductor 57. The adapter 55 fits into a bore in the lower section of the frame 31. The inner and outer shells 54 and 56 are secured to each other by a screw 58 and to the adapter 55 by a threaded section on the end of the inner shell 56. The central conductor 57 is supported by insulating washers 59 and 60. The upper end of the central conductor 57 terminates in a probe 61 which serves to couple the central conductor of the beat-frequency line to the central conductor of the main line of the converter.

The output or intermediate frequency line joins the main line at the coupling block 49. It comprises the outer and inner shells 62 and 63, held together by the screw 64, and a threaded section on the upper end of the inner shell screws into a threaded bore in the lower side of the block 49. The upper end of the central conductor 65 is provided with a point 66, which is soldered to the eyelet 67 carried by the insulating washer 68, and which also extends through a small hole bored in the base of the chuck 50. In this manner the central conductor 65 of the intermediate frequency line is electrically connected through the chuck 50, rectifier base 48 to the rectifying crystal 47. The lower ends of the central conductor 65 and inner shell 63 terminate in a jack by means of which the outgoing circuit is connected to the intermediate frequency line. As illustrated, the cap 69 serves as a guide for the insertion of a connecting plug. However, it will be understood that the intermediate frequency line may have any desired configuration such as the one illustrated in Fig. 1.

In designing the converter structure the length of the rod 36 is chosen such that the length of the exposed part thereof relative to the length of the holder 35 together with other design factors, such as the location of the insulator 42, afford the necessary reactances for bringing the harmonics of the beat-frequency waves into the desired phase relation with the fundamental. Having thus determined the length of the rod 36 it is fixed in place by moving the coupling 33 into the block 31 until the end of the rod fully engages the holder in the chuck 41. The screws 70 are then turned, causing the block 31 to seize and hold the coupling 33 in its adjusted position. Similarly the adapter 55 of the beat-frequency line is moved into the block 31 until the desired degree of coupling is attained, whereupon the screws 71 are tightened to seize and hold said adapter. It will be noted that the block 31 is provided with a saw slot 72 to permit these adjustments.

The by-pass condenser which confines the high frequencies to the main line of the converter is formed by the dielectric space 73 which occurs between the periphery of the shoulder of the chuck 50 and the inner cylindrical surface of the coupling block 49. This is more clearly seen in the enlarged view of Fig. 10. The electrical circuit for the high-frequency currents may be traced therefor from the central concentric conductor 35—36 through the chuck 41, plug 46, rectifier contact wire 45, crystal 47, metallic base 48, chuck 50, high-frequency condenser 73 to the outer concentric conductor of the line comprising the block 49, coupling 33, block 31 and shell 32. The circuit for the intermediate frequency current may be traced from the central conductor 65, point 66, chuck 50, metallic base 48, crystal 47, contact wire 45, plug 46, central conductors 36—35, shell 32, block 31 and thence to the shell 62 constituting the outer concentric conductor of the intermediate frequency line.

Although not limited to any particular material the major parts of this converter are preferably made of brass, and these are plated with a thin coating of gold or silver to insure the maintenance of low resistance electrical contacts where joints occur between the several parts of the structure.

The rectifier unit, which is shown more in detail in Fig. 11, comprises a hollow internally threaded insulating cylinder 91, preferably of ceramic material, housing a silicon rectifying element 47 and a fine contact wire 45, which makes a point engagement with the surface of the silicon crystal. The crystal 47 is secured to a threaded metallic plug 74 which is integral with the metallic base member 48. The contact wire 45 is adjustably secured within a threaded metallic plug 75 which in turn is integral with the metallic cap 76 and plug member 46. Although the silicon element 47 illustrated herein is preferably electropositive, it should be understood that electronegative silicon elements may also be used.

An alternative form of the converter structure is illustrated in Fig. 12. It consists of a frame or block 77 which receives and holds an adjustable shell 78. The opposite end of the shell 78 terminates in a housing block 92 which supports the rectifier element 79 and also forms the outer shell 82 of the intermediate frequency line. The central conductor 80 is supported within the shell 78 by an insulating disc 81. One end of the central conductor 80 is connected to the contact wire of the rectifier, and the crystal of the rectifier is electrically connected to the central conductor 83 of the outlet or intermediate frequency line. A thin layer of dielectric material 93 serves as a by-pass condenser for confining the high-frequency currents to the main line of the converter. The opposite end of the central conductor 80 makes an adjustable engagement with the larger central conductor 84 by means of a central bore in the latter conductor. The conductor 84 is in turn adjustably supported by the block 85, which constitutes a short circuit for the end of the main line. The signal and beat-frequency waves are admitted into the converter through the inlets 86 and 87 respectively, the beat-frequency inlet being equipped with a probe 88 for adjusting the coupling. Also the central conductor 89 which is common to the signal and beat-frequency sources, terminates in a probe 90 for tuning and coupling purposes.

It may be noted that the length of the main line from the rectifier crystal to the short-circuited end 85 is capable of adjustment for bringing the line into tune at a desired frequency. It will also be noted that the sections 80 and 84 of the inner conductor are of different diameters resulting in the presentation of the necessary impedance to the rectifier for causing the generation of harmonics. Furthermore, the relative lengths of these two sections of inner conductor may be varied by the sliding adjustment of section 84 to control the phasing of the fundamental and harmonic waves in the desired manner.

What is claimed is:

1. The combination in a translation system having input and output circuits of a source of signal waves, means for applying said waves to said input circuit, a translating device comprising a crystal and associated contact element for translating the signal waves in said input circuit into signal waves in said output circuit, the translation of said waves resulting in noise currents which appear in the output circuit, said translating device having a characteristic relationship between values of direct voltage applied thereto and said output noise currents in which a positive voltage of critical value of the order of 0.2 to 0.4 volt applied to said crystal with respect to said contact element reduces said noise currents to a minimum whereas greater or smaller values of applied voltage of said polarity and all values of the opposite polarity cause an increase in said noise currents, and circuit means for applying to the terminals of said translating device a direct voltage of said crystal value and of said polarity to substantially eliminate the noise currents in said output circuit.

2. The combination in a translation system having input and output circuits of a source of signal waves, means for applying said waves to said input circuit, a rectifying device comprising a crystal and associated contact element for translating the signal waves in said input circuit into signal waves in said output circuit, the translation of said waves resulting in noise currents which appear in said output circuit, said rectifying device having a characteristic relationship between values of direct voltage applied across the terminals thereof and said output noise currents in which a positive potential of critical value applied to said crystal with respect to said contact element reduces said noise currents to a minimum whereas other values of positive potential and all values of negative potential applied to said crystal with respect to said contact element result in an increase in said noise currents, the value of said critical potential being too low to affect the signal waves in said output circuit, and circuit means for applying to the terminals of said rectifying device a direct voltage of said critical value and of said polarity for substantially eliminating the noise currents from the output circuit without affecting the signal waves therein.

3. The combination in a system for converting signal waves of high-frequency into signal waves of intermediate frequency of a converter comprising input sections, a converting section, and an output section all physically joined to form a unitary structure, a source of high-frequency signal waves, a source of beat-frequency waves, means for connecting said sources to said input sections, a translating element removably attached to said converting section, coupling means for conducting the waves in said input sections by way of the converting section to said translating element, the length of said converting section being chosen to tune it to said high-frequency waves, by-pass means near the junction of the converting and output sections for excluding the high-frequency waves from said output section, the length of said output section being chosen to bring the end thereof into coincidence with the nodal point of the intermediate frequency waves therein, a source of direct voltage, a circuit connecting said source to the nodal point of said output section for applying the voltage thereof across said translating element, and by-pass means at said nodal point for excluding said intermediate frequency waves from the circuit to said voltage source.

4. The combination in a system for converting signal waves of high-frequency into signal waves of intermediate frequency of a converter comprising input sections, a converting section, and an output section, said sections formed of hollow and concentric conductors and physically joined to form a unitary structure, a signal source of microwaves, a source of beat-frequency waves, means for connecting said sources to said input sections, a crystal rectifying element removably attached to said converting section, coupling means for conducting the waves in said input sections by way of the converting section to said rectifying element, means for adjusting the length of said converting section to tune it to the waves received from the input sections, by-pass means for excluding the high-frequency waves from said output section, the length of said output section being chosen to bring the end thereof into coincidence with the nodal point of the intermediate frequency waves therein, a source of direct voltage, circuit means for connecting said source of direct voltage to the nodal point of said output section for applying the voltage thereof across said rectifying element, and by-pass means for excluding said intermediate frequency waves from said direct voltage source.

5. The combination in a frequency converter of a main transmission line comprising an outer hollow conductor and an inner concentric conductor, a source of high-frequency waves, means for impressing the waves from said source upon said line, a translating device in said line for translating said high-frequency waves into waves of a lower frequency, said inner conductor being formed in sections of different thicknesses for causing the production in said line of harmonics of the fundamental frequency of said source, the relative lengths of the sections of said inner conductor being proportioned to control the phase relation of the fundamental and harmonic waves in said line, and an output line connected with said first line for receiving the waves of translated frequency.

6. The combination in a frequency converter of a main transmission line comprising an outer hollow conductor and an inner concentric conductor, a source of high-frequency waves, means for impressing the waves from said source upon said line, a translating device in said line for translating said high-frequency waves into waves of a lower frequency, said inner conductor having two sections of different diameters for presenting an impedance to said translating device for causing the latter to generate in said line waves of a harmonic frequency relative to the fundamental frequency of said source, means for varying the ratio of the lengths of said sections of inner conductor to vary the phase relation between the waves of fundamental frequency and the waves of harmonic frequency in said line, and an output line connected with said main line for receiving the waves of translated frequency.

7. The combination in a frequency converter of a main transmission line comprising an outer

hollow conductor, an inner concentric conductor formed in sections of different diameters, a source of energy of high-frequency, means for impressing energy from said source upon said line, a translating device in said line for translating the energy from said source into signal energy of a lower frequency, and an output line connected with said first line for receiving said translated signal energy, the length of said sections of inner conductor being chosen to increase the signal energy appearing in said output line.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,144,655	Hahnle	Jan. 24, 1939
1,526,408	Young	Feb. 17, 1925
2,253,503	Bowen	Aug. 26, 1941
2,253,589	Southworth	Aug. 26, 1941
2,408,420	Ginzton	Oct. 1, 1946
2,378,944	Ohl	June 26, 1945

FOREIGN PATENTS

Number	Country	Date
463,238	Great Britain	Mar. 24, 1937
116,110	Australia	Nov. 19, 1942