

June 11, 1940.

P. S. CARTER

2,204,175

ANTENNA SYSTEM

Filed Jan. 19, 1939

2 Sheets-Sheet 1.

Fig. 1

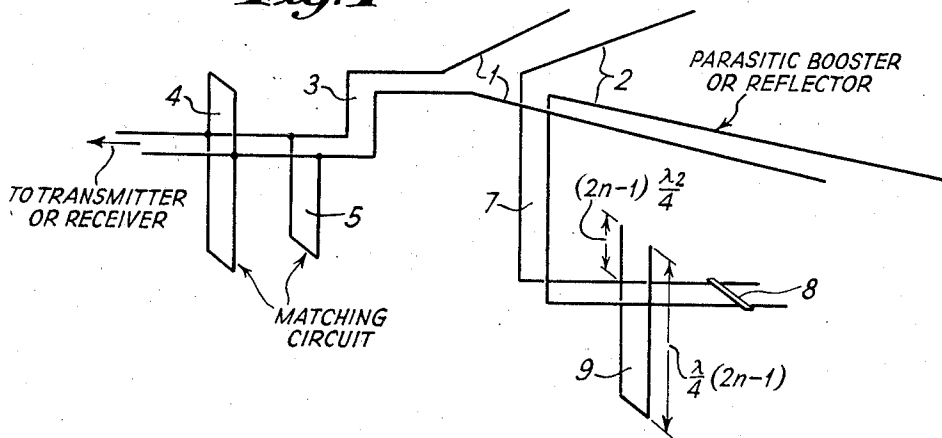


Fig. 2

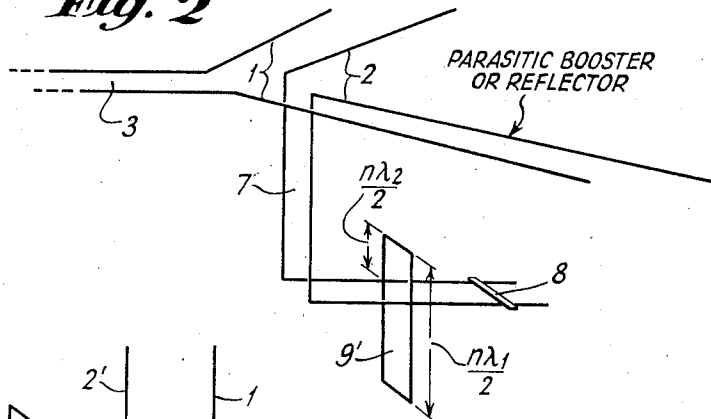
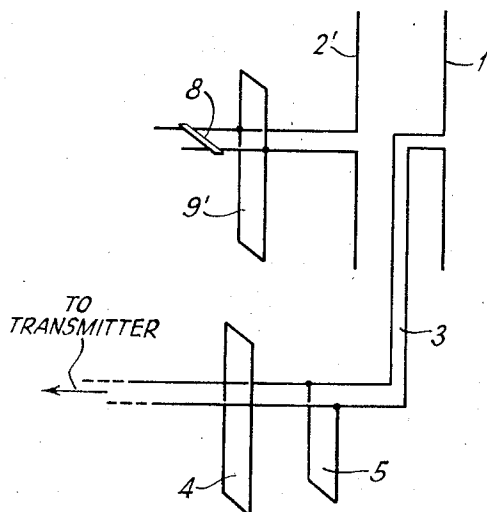


Fig. 3



BY

INVENTOR.
PHILIP S. CARTER

H. S. Snover
ATTORNEY.

June 11, 1940.

P. S. CARTER

2,204,175

ANTENNA SYSTEM

Filed Jan. 19, 1939

2 Sheets-Sheet 2

Fig. 4

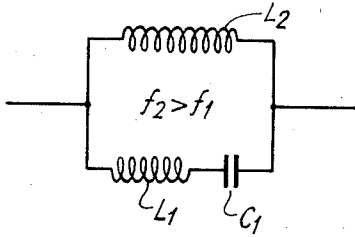


Fig. 5

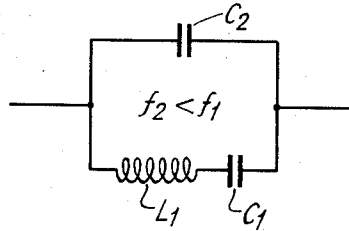


Fig. 6

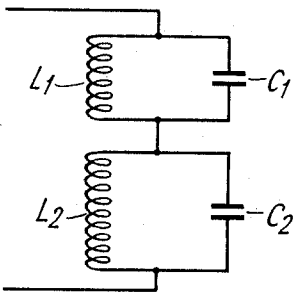


Fig. 7

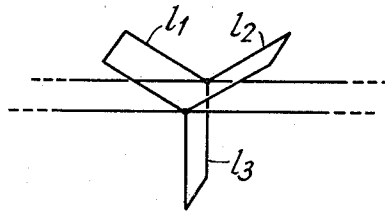
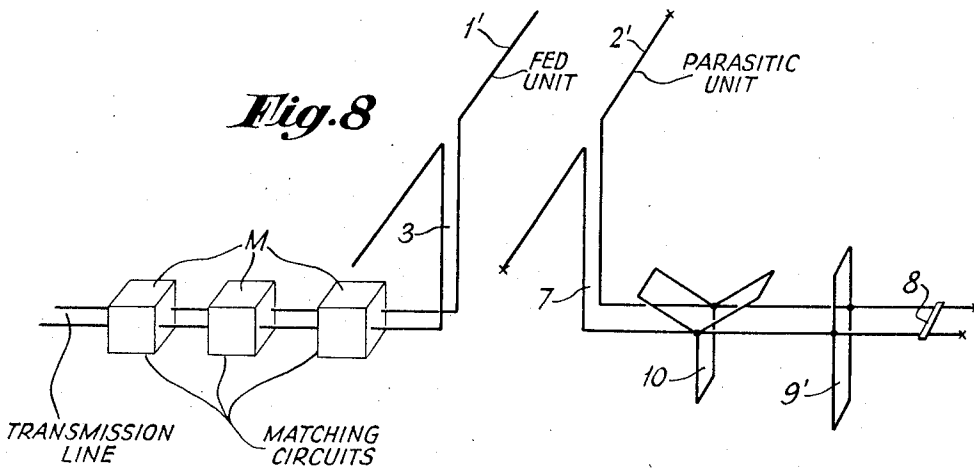


Fig. 8



BY

INVENTOR.
PHILIP S. CARTER

H. S. Snover

ATTORNEY.

UNITED STATES PATENT OFFICE

2,204,175

ANTENNA SYSTEM

Philip S. Carter, Port Jefferson, N. Y., assignor to
Radio Corporation of America, a corporation
of Delaware

Application January 19, 1939, Serial No. 251,743

16 Claims. (Cl. 250—33)

This invention relates to antenna systems, and particularly to an antenna system adapted for operation on two or more frequencies. More specifically, the invention is concerned with an antenna system having a directly excited unit and one or more parasitic (i. e., floating) units. The parasitic unit is an antenna unit which is floating; that is, excited solely through the space between the floating unit and the directly excited unit, and may comprise either a reflector or a so-called "booster," the latter of which is sometimes referred to as a director.

It is known to use a directly energized antenna unit on a plurality of different frequencies, wherein the transmission line has connected across it circuits of such constants that the antenna system matches the characteristic impedance of the line for the different operating frequencies. These circuits across the transmission line are so proportioned that the adjustment of the impedance matching for any one frequency has no effect upon other adjustments for other frequencies. This may be accomplished, according to known practice, by matching the impedance at a particular frequency by means of a special circuit so that at certain predetermined other frequencies the particular circuit has an infinite impedance and acts like an open circuit for those other frequencies. When two frequencies are involved, the actual circuit employed in matching the impedance of the system may take any one of a number of forms, such as a lumped reactance, a line section closed at both ends, or a line section closed at one end in the form of a U, or a line open at both ends. In this manner a single antenna system may be used simultaneously with high efficiency on two or more frequencies. Such an arrangement, known in the art, is described in my copending application Serial No. 31,756, filed July 17, 1935, and in the copending application of Philip H. Smith, Serial No. 5,694, filed February 9, 1935.

It is also known to employ an antenna system comprising a directly excited unit having associated therewith reflector and/or booster parasitic units. The reflector unit is the unit located behind the directly excited unit with respect to the direction of transmission or reception, while the booster unit, sometimes called the director, is located ahead of the directly excited unit with regard to the direction of transmission or reception. Examples of antenna systems using directly excited and parasitic units are to be found in Carter Patent No. 2,040,079, granted May 12,

1936, and Moser Patent No. 2,112,301, granted March 29, 1938.

The present invention teaches how an antenna system employing a directly excited unit and a parasitic unit, either a reflector or a booster, or both, can be made to function with high efficiency on two or more frequencies. Briefly, the invention contemplates the use of an antenna whose units are each made of two arms, such as a V antenna, or a dipole, whose adjacent ends are connected through a section of transmission line. Where the unit is a booster or a reflector, the section of transmission line will, of necessity, be a floating section connecting together the adjacent ends of this parasitic unit. It is proposed, in accordance with the invention, to connect a plurality of circuits across the section of transmission line directly associated with the parasitic unit, in order to enable the antenna system as a whole to be used on a plurality of frequencies.

Although the invention will be hereinafter described with particular reference to V-type and dipole type antennae, it should be distinctly understood that these types of antennae have been selected merely because of their simplicity, and not because of any limitation in the application of the principles of the invention. The invention is applicable to different types of antennae and to various arrays thereof.

A more detailed description of the invention follows in conjunction with the drawings, wherein:

Figs. 1 and 2 show the principles of the invention applied to a V-type antenna;

Fig. 3 shows the principles of the invention applied to the dipole type of antenna;

Figs. 4 and 5 illustrate lumped tuned circuits which may be used as shunt elements across the parasitic unit transmission line in place of the line section circuits shown in Figs. 1, 2 and 3;

Fig. 6 illustrates a circuit of lumped constants for use when three frequencies are employed on the antenna system;

Fig. 7 shows a three branch line section circuit which may be used when three frequencies are employed on the antenna system; and

Fig. 8 shows the application of the circuit of Fig. 7 to a dipole antenna system.

Fig. 1 shows an antenna system either for receiving or transmitting purposes, comprising a directly excited V antenna 1, and a V-type parasitic reflector or booster 2. Both of these units 1 and 2 each comprise a pair of diverging wires which are excited with energy of opposite in-

stantaneous polarity at their more closely spaced ends, the angle between the wires of each V being determined in a manner which is disclosed in my United States Patent No. 1,974,387, granted September 18, 1934. Directly excited unit 1 is connected to suitable high frequency transmitting or receiving apparatus through a two conductor transmission line 3, across which there are provided two impedance matching circuits 4, 5 in order to enable the antenna unit 1 to function on two different frequencies. Impedance matching circuits 4 and 5 are so designed and so located with respect to each other that circuit member 5 matches the antenna 1 to the transmission line 3 for one frequency, while circuit 4 matches the load consisting of antenna 1 together with circuit 5 for another frequency while presenting substantially infinite impedance to energy of the first frequency. Of course, where desired, circuit 5 may be designed also to present substantially infinite impedance to energy of the second frequency. The particular principles covering this form of impedance matching are described in my copending application Serial No. 31,756, and the copending application of Smith, Serial No. 5,694, supra. If we are to assume that unit 2 is located ahead of unit 1 in the direction of transmission or reception, then unit 2 will be a booster or director, while if we assume that unit 2 is located behind unit 1 with respect to the direction of transmission or reception, then unit 2 is a reflector. The more closely spaced ends of parasitic unit 2, which it will be noted is floating with respect to unit 1, are coupled together by means of a stub or short section of transmission line 7 across which there are placed a short circuiting strip 8 for tuning unit 2 to energy of the first frequency, and a circuit 9 for tuning the unit 2 to energy of the second frequency, while this last circuit at the same time presents substantially infinite impedance to energy of the first frequency.

The manner in which the circuits 8 and 9 are connected across stub or line section 7 will now be described. Let us designate the two frequencies on which the antenna system is to function by the symbols f_1 and f_2 . Assuming that circuit 9 is not connected across stub 7 and the antenna system is excited with energy of the frequency f_1 , the parasitic unit 2 is first adjusted to give maximum radiation in the desired direction at the frequency of f_1 by moving short circuiting strip 8 along the stub 7. When this adjustment is obtained, strip 8 is then left permanently connected across the stub 7. Strip 8 is placed in a position to allow plenty of room for the adjustment of another circuit at a convenient location between it and the parasitic antenna unit 2. Since the effect of short circuiting strip 8 is the same if it is moved to any point which is an exact multiple of one-half wave-length at frequency f_1 from a position giving the best results, it will be obvious that the strip can have any one of a plurality of possible positions for tuning the parasitic unit to give maximum radiation. Having made the foregoing adjustment for the frequency f_1 , and with the short circuiting strip 8 permanently connected across the stub 7, the antenna system is excited with energy of the frequency f_2 and a position found for another temporary short circuiting strip which will give maximum radiation for energy of the frequency f_2 . Now the temporary short circuiting strip employed for the frequency f_2 should be replaced by a circuit such as 9, which has the

characteristic of acting as an open circuit, that is, infinite impedance, to energy of the first frequency f_1 , and a short circuit to energy of the frequency f_2 .

The circuit 9 shown in Fig. 1 is a U loop having an overall length equal to an odd multiple of one-quarter of a wave-length corresponding to frequency f_1 , this wavelength being designated as λ_1 . The U loop is connected to the transmission line stub 7 at a distance from the open end of the U equal to an odd multiple of one-quarter of a wavelength corresponding to the frequency f_2 . If the wavelength at the frequency f_2 is designated by the symbol λ_2 , then this last connection will be at a distance from the open end of the U loop equal to

$$\frac{\lambda_2}{4}$$

It should be noted, of course, that the point of connection of the U loop 9 to the stub 7 is at the location of the previous temporary short circuiting strip, as described above. Although the circuit 9 is shown connected to stub 7 at a location which is equal to an odd multiple of

$$\frac{\lambda_2}{4}$$

from its open end, it should be distinctly understood that the same loop also has the desired characteristic if the connection to the transmission line stub 7 is made at a distance from the closed end of the U (the trough) equal to any multiple of

$$\frac{\lambda_2}{2}$$

Fig. 2 shows a similar antenna system as Fig. 1, in accordance with the invention, except that now the impedance matching circuit for the second frequency f_2 is a loop 9' closed at both ends, instead of the previously described U-shaped loop. The over-all length of loop 9' is equal to any multiple of

$$\frac{\lambda_1}{2}$$

and the distance of the junction points of circuit 9 and the transmission line stub 7 from either closed end of the loop 9' is any multiple of

$$\frac{\lambda_2}{2}$$

The principles of operation and the method of matching the impedances are the same as described in connection with Fig. 1, for which reason it is not believed necessary to repeat them here. In order to simplify the drawing of Fig. 2, the impedance matching circuits 4 and 5 connecting with transmission line 3, as shown in Fig. 1, have been omitted.

Fig. 3 illustrates another embodiment of the invention wherein dipoles are used instead of V antennae. Except for the showing of the dipole antennae instead of the V antennae, the same elements appearing in Fig. 3 appear in Figs. 1 and 2, with the same reference numerals. The principle of operation and adjustment of Fig. 3 being identical with that of Figs. 1 and 2, it is not believed necessary to repeat the operation of Fig. 3.

Although the parasitic unit 2 of Figs. 1 and 2 is shown to the right of the directly excited unit 1, while the parasitic unit 2' of Fig. 3 is shown to the left of the parasitic unit 1, it should be distinctly understood that it is immaterial in the practice of the present invention whether

the parasitic unit be to the right or the left of the directly excited unit with respect to the line of transmission or reception, and that, if desired, a parasitic unit can be placed both on the right and the left of the directly excited unit. Care should be taken, however, whether the unit be placed to the right or to the left of the directly excited unit, that the adjustment be made to have it function in accordance with its intended purpose (either as a reflector or as a booster); that is, to assist the directly excited unit in the particular desired direction. Although the principles underlying the method of tuning are generally the same in both cases of reflector and booster, the particular positions of the circuits 8 and 9 will be quite different.

Figs. 4 and 5 show lumped reactance circuits of inductance and capacitance which may be used instead of the transmission line loops 9 and 9' in certain cases. The lumped circuit of Fig. 4 may be used when the frequency f_1 is less than the frequency f_2 , while the lumped circuit of Fig. 5 may be used when the frequency f_1 is greater than the frequency f_2 .

When the lumped circuit of Fig. 4 is used, the inductance and capacity elements thereof are properly proportioned so that at frequency f_1 , the lower series arm comprising L_1 , C_1 acts as a capacity reactance equal to the inductive reactance of arm L_2 , thus making the whole circuit in effect a parallel tuned circuit giving very high impedance (infinity when losses are neglected) to currents of the frequency f_1 . At frequency f_2 , the inductive reactance of L_1 will equal the capacity reactance of C_1 , thus producing a series tuned circuit which is equivalent to a short circuit at that frequency.

Concerning the lumped tuned circuit of Fig. 5, the reactance elements are properly proportioned so that at frequency f_1 the inductive reactance of the lower series arm L_1 , C_1 is equal to the capacity reactance of the upper arm C_2 , thus making the whole circuit in effect a parallel tuned circuit having a high impedance (infinity if we neglect losses) for energy of the frequency f_1 . At frequency f_2 , the capacitive reactance of C_1 will be equal to the inductive reactance of L_1 , thus producing a short circuit through the lower series arm for the energy of the frequency f_2 .

For the lumped tuned circuit of Fig. 4, the capacity and inductance elements should satisfy the following relations:

$$\omega_2^2 L_1 C_1 = 1; \left(\frac{\omega_1}{\omega_2} \right)^2 = \frac{1}{1 + \frac{L_2}{L_1}}$$

where $\omega_1 = 2\pi f_1$ and $\omega_2 = 2\pi f_2$ and $\omega_1 < \omega_2$.

For the lumped circuit of Fig. 5, the capacity and inductance elements should satisfy the following relations:

$$\omega_2^2 L_1 C_1 = 1; \left(\frac{\omega_1}{\omega_2} \right)^2 = 1 + \frac{C_1}{C_2}$$

where $\omega_1 = 2\pi f_1$ and $\omega_2 = 2\pi f_2$ and $\omega_1 < \omega_2$.

Although the invention has been described in connection with two frequencies, it should be understood that the principles thereof may be employed in connection with three or more frequencies. Where a third frequency f_3 is used, a third adjustment should be made at this frequency using a circuit which acts as an open circuit for both f_1 and f_2 and a short circuit at f_3 . Such a circuit, if made up of transmission line sections, except for particular frequency ratios, must consist of three branches, unless a line stub

of inconveniently great length is used. If the circuit is of the lumped circuit type, it must contain at least two inductances and two capacities.

Fig. 6 shows a circuit of lumped constants which has the necessary impedance characteristic for shunting the line stub when a third frequency is to be used, i. e., its impedance is infinite at frequencies f_1 and f_2 and zero (neglecting losses) at frequency f_3 if f_3 lies between f_1 and f_2 . It contains four elements L_1 , L_2 , C_1 and C_2 . If f_3 is not chosen to lie between f_1 and f_2 , a circuit having five elements is necessary to give the desired characteristic. For this reason the circuit of Fig. 6 is a preferred type of circuit having lumped reactances.

The required constants are easily obtained for any specified three frequencies from the relations below where it is assumed that $f_1 < f_3 < f_2$, and $\omega a = 2\pi f a$ ($a=1, 2, 3$).

$$\omega_1^2 = \frac{1}{L_1 C_1}, \omega_2^2 = \frac{1}{L_2 C_2}, \frac{L_1}{L_2} = \frac{\omega_3^2 - \omega_1^2}{\omega_2^2 - \omega_3^2}$$

If the circuit for the third frequency consists of stub line sections, it may consist of three open line sections in parallel, three closed line sections in parallel, as shown in Fig. 7, and/or combinations of three open and closed line sections. The preferred combination depends in part at least upon the particular three frequencies involved.

When all line stub sections are closed, the lengths must be such that the three relations below are satisfied. Here l_1 , l_2 and l_3 are the lengths of the respective stubs c , the velocity of light in the same units as l , and $\omega_1, \omega_2, \omega_3$ the angular frequencies corresponding to f_1 , f_2 and f_3 .

$$\cot \frac{\omega_1 l_1}{c} + \cot \frac{\omega_1 l_2}{c} + \cot \frac{\omega_1 l_3}{c} = 0$$

$$\cot \frac{\omega_2 l_1}{c} + \cot \frac{\omega_2 l_2}{c} + \cot \frac{\omega_2 l_3}{c} = 0$$

$$\cot \frac{\omega_3 l_1}{c} + \cot \frac{\omega_3 l_2}{c} + \cot \frac{\omega_3 l_3}{c} = \infty$$

When one or more of the line stubs are open ended, similar relations hold if the cotangent function related to a particular stub section which is to be open ended is replaced with the tangent function.

Fig. 8 shows an antenna system of the present invention adapted for operation on three frequencies. Both the directly excited antenna unit 1' and the parasitic unit 2' are shown as being of the dipole type, although it will be understood that, if desired, a V-type antenna can be used to replace each of the dipoles. The directly excited antenna unit 1' is shown connected to a transmission line through three impedance matching circuits M, herein indicated diagrammatically in box form. These matching circuits are so designed and located with respect to each other that each matches the antenna to the transmission line for one frequency while presenting substantially infinite impedance to energy of the other frequencies. As for the parasitic unit comprising the antenna 2', the stub section of transmission line 7 and the three shunting circuits 8, 9' and 10, located across the stub 7, the short circuiting strip 8 is used for one of the frequencies, let us say f_1 to give maximum radiation in the desired direction at this frequency, while circuit 9' is used to provide a short circuit for a secondary frequency f_2 , and an open circuit for the first frequency f_1 , and the third circuit 10 is arranged to provide a short circuit for energy of the third frequency f_3 .

and an open circuit for energy of the first two frequencies f_1 and f_2 . The method of adjusting the system of Fig. 3 is exactly the same for the third frequency as that previously explained for the second frequency. Putting it another way, we can say we first locate the proper position for the third circuit by first using a temporary shorting bar or strip and then in place of this bar substituting a circuit which has a very high impedance at the frequencies f_1 and f_2 and a very low impedance at the frequency f_3 .

The term "multiple" used in the specification and the appended claims is deemed to include unity.

15 What is claimed is:

1. An antenna system including one or more parasitic units, and a plurality of circuits connected to said parasitic units and being so proportioned and located as to result in high radiation efficiency at two or more frequencies.

2. An antenna system including a parasitic unit for use at two frequencies, said parasitic unit having two arms whose adjacent ends are connected together by a pair of conductors, a circuit of low impedance to radio frequency energy for one frequency coupled across said conductors for tuning said parasitic unit for maximum radiation or reception, and another circuit connected across said conductors and located between said parasitic unit and said circuit of low impedance for tuning said parasitic unit for maximum radiation or reception at energy of a second frequency.

3. A system in accordance with claim 2, characterized in this that said second circuit is a circuit of low impedance to energy of the second frequency and of very high impedance to energy of the first frequency.

4. An antenna system including a parasitic unit for use at two frequencies, said parasitic unit having two arms whose adjacent ends are connected together by a pair of conductors, a strip of metal of low impedance to radio frequency energy for one frequency coupled across said conductors for tuning said parasitic unit for maximum radiation or reception, and a circuit connected across said conductors and located between said parasitic unit and said strip of metal for tuning said parasitic unit for maximum radiation or reception at energy of a second frequency, said circuit being of low impedance to energy of the second frequency and of very high impedance to energy of the first frequency.

5. An antenna system adapted for operation on a plurality of different frequencies including a parasitic unit, a transmission line in circuit with said parasitic unit, a first circuit permanently bridged across said line for tuning said parasitic unit for efficient radiation or reception at one frequency, and a second circuit permanently bridged across said line and located between said first circuit and said parasitic unit for efficient radiation or reception at another frequency, said second circuit being so designed as to present very high impedance to energy of the first frequency and very low impedance to energy of the said other frequency.

6. An antenna system in accordance with claim 5, characterized in this that said parasitic unit is a V antenna.

7. An antenna system in accordance with claim 5, characterized in this that said parasitic unit is a dipole antenna.

8. An antenna system adapted for operation on a plurality of different frequencies including

a parasitic unit, a transmission line in circuit with said parasitic unit, a first circuit permanently bridged across said line for tuning said parasitic unit for efficient radiation or reception at one frequency, and a second circuit permanently bridged across said line and located between said first circuit and said parasitic unit for efficient radiation or reception at another frequency, said second circuit comprising a loop in the form of a section of two-conductor line connected at points intermediate its ends to said transmission line and being so designed as to present very high impedance to energy of the first frequency and very low impedance to energy of the said other frequency.

9. An antenna system adapted for operation on a plurality of different frequencies including a parasitic unit, a transmission line in circuit with said parasitic unit, a first circuit permanently bridged across said line for tuning said parasitic unit for efficient radiation or reception at one frequency, and a second circuit permanently bridged across said line and located between said first circuit and said parasitic unit for efficient radiation or reception at another frequency, said second circuit being a line section in the form of a U connected intermediate its ends to said transmission line, the distance between the open ends of said U and the junction points of said transmission line being an odd multiple of one-quarter wavelength at said other frequency, said said circuit being so designed as to present very high impedance to energy of the first frequency and very low impedance to energy of the said other frequency.

10. An antenna system adapted for operation on a plurality of different frequencies including a parasitic unit, a transmission line in circuit with said parasitic unit, a first circuit permanently bridged across said line for tuning said parasitic unit for efficient radiation or reception at one frequency, and a second circuit permanently bridged across said line and located between said first circuit and said parasitic unit for efficient radiation or reception at another frequency, said second circuit being a line section in the form of a loop closed at both ends, and connected intermediate its ends to said transmission line, the distance from one closed end of said loop to said transmission line being a multiple of one-half the wavelength at the second frequency, said second circuit being so designed as to present very low impedance to energy of the first frequency and very low impedance to energy of the said other frequency.

11. An antenna system in accordance with claim 5, characterized in this that said second circuit comprises an inductance connected in parallel to a series circuit of inductance and reactance.

12. An antenna system in accordance with claim 5, characterized in this that said second circuit comprises a capacitance connected in parallel to a series circuit of inductance and capacitance.

13. An antenna system including a parasitic unit for use at three frequencies, said parasitic unit having two arms whose adjacent ends are connected together by a pair of conductors, a circuit of low impedance to radio frequency energy for one frequency coupled across said conductors for tuning said parasitic unit for maximum radiation or reception, another circuit connected across said conductors and located between said parasitic unit and said circuit of

low impedance for tuning said parasitic unit for maximum radiation or reception at energy of a second frequency, and a third circuit connected across said conductors and of low impedance to radio frequency energy of the third frequency, but of very high impedance to energy of the first two frequencies.

14. An antenna system in accordance with claim 13, characterized in this that said three circuits comprise two-conductor line sections.

15. An antenna system including a parasitic unit for use at three frequencies, said parasitic unit having two arms whose adjacent ends are connected together by a pair of conductors, a circuit of low impedance to radio frequency energy for one frequency coupled across said conductors for tuning said parasitic unit for maximum radiation or reception, another circuit of high impedance to energy of said one frequency connected across said conductors and located between said parasitic unit and said circuit of low impedance for tuning said parasitic unit for maximum radiation or reception at

energy of a second frequency, and a third circuit connected across said conductors and of low impedance to radio frequency energy of the third frequency, but of very high impedance to energy of the first two frequencies, said third circuit being connected between said parasitic unit and said second circuit.

16. An antenna system including a parasitic unit for use at two frequencies, said parasitic unit having two arms whose adjacent ends are connected to one end of a pair of parallel conductors, a circuit of low impedance to radio frequency energy for one frequency coupled across said conductors for tuning said parasitic unit for maximum radiation or reception at said one frequency, and another circuit of high impedance to energy of said first frequency and of low impedance to energy of the second frequency connected across said conductors for tuning said parasitic unit for maximum radiation or reception at energy of said second frequency.

PHILIP S. CARTER.