

Feb. 17, 1959

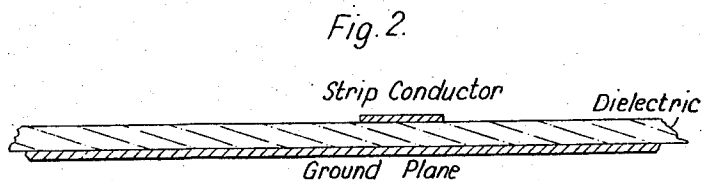
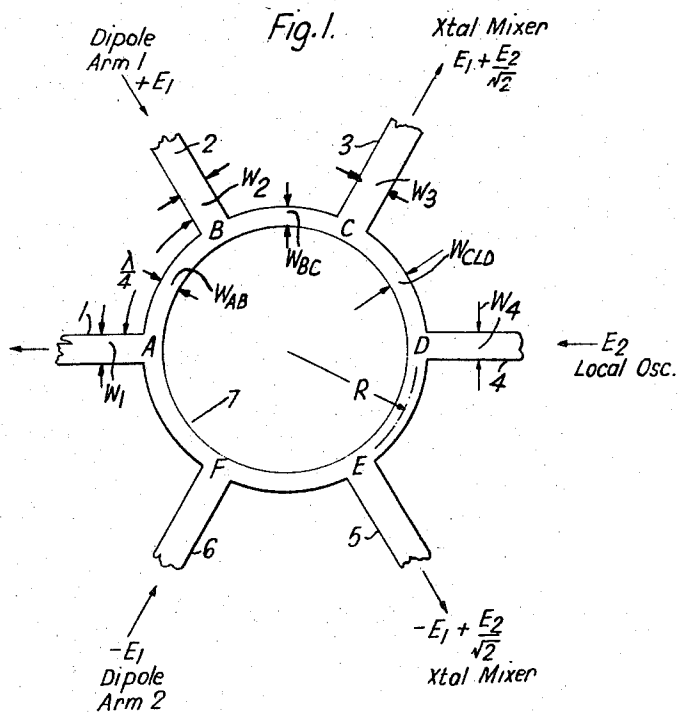
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UNITARY ANTENNA-RECEIVER UTILIZING MICROSTRIP CONDUCTORS

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3 Sheets-Sheet 1



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Fig. 3.

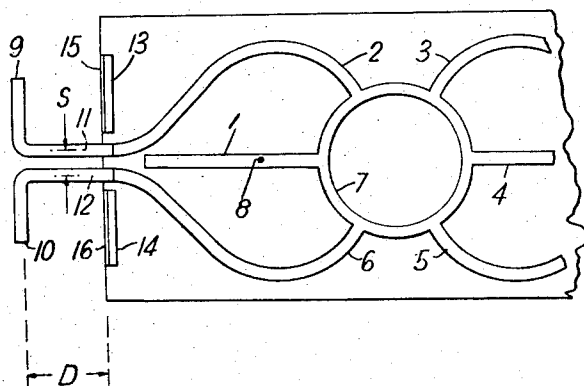


Fig. 4.

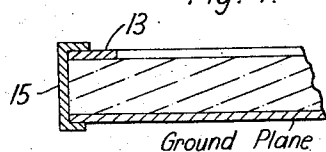
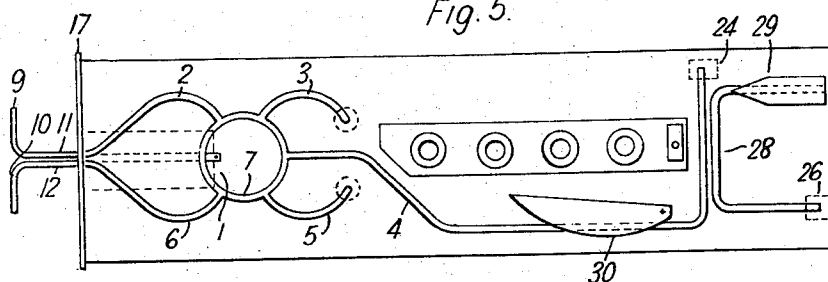


Fig. 5.



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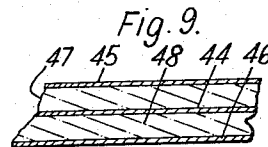
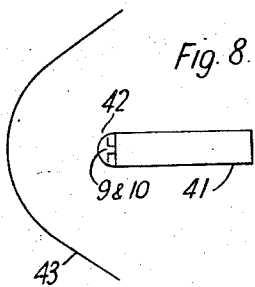
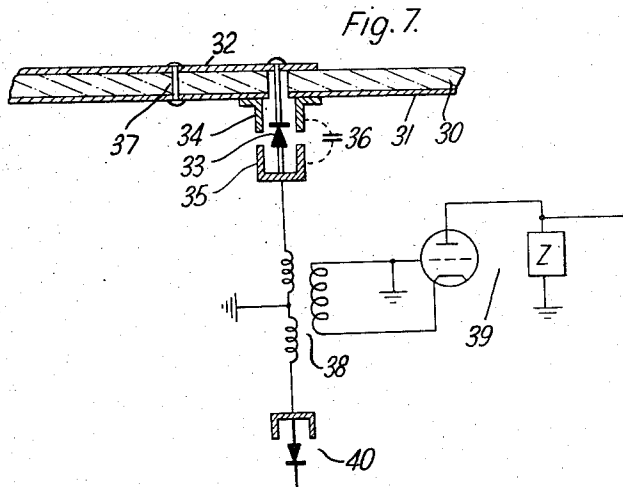
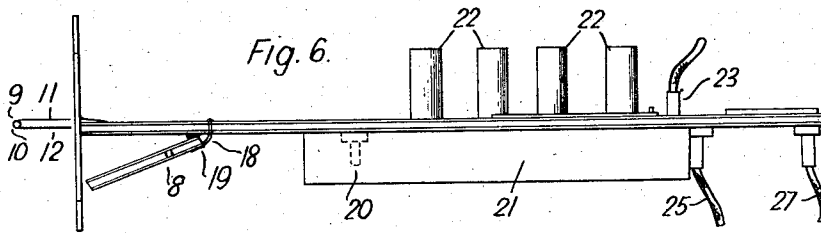
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3 Sheets-Sheet 3



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2,874,276

UNITARY ANTENNA-RECEIVER UTILIZING MICROSTRIP CONDUCTORS

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Application November 4, 1954, Serial No. 466,753

Claims priority, application Great Britain November 13, 1953

2 Claims. (Cl. 250—20)

This invention relates to radio waveguide systems. More particularly, it relates to waveguide systems of the type frequently referred to as "strip line," or "microstrip," formed by metallic strip conductor separated from a metallic plane surface by a thin layer of dielectric, and to microwave antenna heads embodying such systems.

A main object of the invention is to provide a microwave antenna head capable of covering a bandwidth of the order of 10% to 15%, and readily changeable from one band to another.

According to the most general aspect of the invention there is provided a microwave antenna head comprising a closed waveguide loop and waveguide extensions from said loop connected respectively to an antenna and to a transmitting (or receiving) element in which said waveguide loop and said waveguide extensions are in planar form constituted by a dielectric sheet on one side of which is a planar metallic conductor and on the other side of which are printed strip conductors spaced apart from said plane metallic conductor by said dielectric sheet a small fraction of a wave length.

According to a more restricted aspect of the invention there is provided a microwave receiving antenna head comprising a dipole antenna, a source of beating oscillations, a balanced detector, a closed waveguide loop having a mean perimeter equal to $6N$ quarter wavelengths at the mean operating frequency, where N is an odd integer, and a plurality of coupling waveguide sections, one of said waveguide sections serving to couple said source of beating oscillations to said loop at a given point thereon, two other of said waveguide sections serving to couple separately the two halves of said balanced detector to said loop at respective points spaced N quarter wavelengths to either side of said first mentioned point, and two further of said waveguide sections serving to couple separately the two halves of said dipole antenna to said loop at respective points spaced $2N$ quarter wavelengths to either side of said first mentioned point.

The invention will be better understood from the following description of an embodiment, taken in conjunction with the accompanying drawings, in which:

Figs. 1 and 2 illustrate respectively plan and elevation views of a hybrid junction;

Fig. 3 shows the manner in which the antenna elements are coupled to the hybrid junction of Fig. 1;

Fig. 4 illustrates a detail of Fig. 3;

Figs. 5 and 6 illustrate the complete R. F. head in plan and section respectively;

Fig. 7 illustrates the manner in which the output of the R. F. head is coupled to the main body of the receiver;

Fig. 8 illustrates the relative disposition of the R. F. head and a cooperating parabolic reflector;

Fig. 9 illustrates an alternative form of strip line construction which may be used in the embodiments.

The same reference numeral is used through out the several figures to indicate the same part.

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The R. F. head now to be described is intended for use in a microwave receiving system for incorporation in propagation testing equipment to be used in any of the frequency bands 1700–2300, 3600–4200, 4400–5000, 6000–8000, and 9800–10000 mc./s. In view of the wide range of frequencies likely to be employed, and the virtual impossibility of covering all the bands simultaneously, it is necessary that the R. F. head should be capable of cheap and simple modification when changing frequency band, and that within each band the head should possess the widest possible bandwidth without need of modification. It is further desirable that the head should have the following properties: (a) low initial cost; (b) ease of assembly; (c) lightness of weight; (d) sufficiently small size to mount in front of a parabolic mirror without causing a deterioration in the radiation pattern of the mirror; (e) performance comparable with that of conventional systems.

Referring now to the drawings, an important element in a microwave receiving antenna head which constitutes an embodiment of the invention is a hybrid junction illustrated in Figs. 1 and 2. This junction takes the form of a closed waveguide loop 7 having a plurality of coupling waveguide sections or arms 1 to 6 spaced round the loop. In the present embodiment the waveguide loop and the coupling waveguide sections are constructed in planar (or more specifically "microstrip") form, the assembly comprising a metallic strip first conductor, shaped in the form shown in Fig. 1, and printed, or otherwise supported, on a dielectric slab which on its lower side, as shown in Fig. 2, supports a second metal conductor which acts as species of "ground plane."

The hybrid junction illustrated in Fig. 1 is so proportioned that:

(1) The six arms 1–6 are spaced apart one quarter of a wavelength, or an odd multiple of one quarter of a wavelength. Accordingly the mean radius R of the circular ring 7 is so adjusted that the above arm spacing is correctly maintained, i. e., so that the loop has a mean perimeter equal to $6N$ quarter wavelengths, where N is an odd integer. This requires knowledge of the velocity of propagation of the system, which may easily be determined by measurement.

(2) The width W_1, W_2, W_3 etc., of the conductors 1–6 are so chosen in relation to the thickness of the dielectric that the characteristic impedances of the arms have certain values selected in accordance with the requirements of the external circuits.

(3) The widths W_{AB}, W_{BC}, W_{CD} , etc., of the individual sections AB, BC, etc., of the loop conductor 7 are so chosen as to satisfy the basic design relationship

$$Z_2 Z_3 = (Z_{CD})^2$$

and

$$Z_1 Z_2 = (Z_{BC})^2$$

where Z_1 is the characteristic impedance of the arms 2 and 6, Z_2 that of arms 3 and 5, and Z_3 that of arm 4, while Z_{CD} is the characteristic impedance sections CD and ED of the loop, 7, and Z_{BC} is the characteristic impedance of the sections BC and FE of loop 7.

The arm 1 is electrically short-circuited at a point which is distant from ring 7 by odd number of quarter wavelengths so explained hereinafter characteristic impedance of the loop sections AB and AF on either side of arm 1 is not critical.

The principles of operation of the hybrid junction illustrated in Fig. 1 are briefly as follows. Arms 2 and 6 are connected to the two arms of a receiving dipole assembly. Now it is an inherent and well known property that the voltage induced in one arm of a dipole is 180° out of phase with the voltage induced in the other

arm. Thus we may represent the voltages applied to the arms 2 and 6 of the hybrid junctions as E_1 and $-E_1$ respectively.

Now the currents entering arms 2 and 6 of the junction divide and then recombine at the other arms with such relative phase shifts as to form the following outputs:

- (1) Zero output at arm 4.
- (2) Zero output at arm 1.
- (3) An output at arm 3.

(4) An output at arm 5, which is equal in magnitude but in phase opposition to the output at arm 3.

It may also be shown that the local oscillator power entering at arm 4 divides equally between arms 3 and 5, and no power is absorbed in either arms 1, 2 or 6. This is an important advantage of the structure in that the antenna and local oscillator circuits are thereby isolated. No signal power is lost in the oscillator circuit, and no oscillator power is radiated by the antenna.

Now it will be noted that whereas the voltages induced in arms 3 and 5 by the antenna circuit are 180° out of phase the voltages induced in arms 3 and 5 by the local oscillator circuit are in phase. Hence if we use a balanced crystal mixer circuit of the form illustrated in Fig. 7, it can be shown that:

(1) The fundamental frequency component of the local oscillator signal cancels in the transformer coil 38 in Fig. 7. This eases the design of the mixing circuit in that no special precautions are required to ensure that negligible local oscillator signal appears at the grid of the first amplifier 39.

(2) Any noise or other modulation of the local oscillator signal which may modulate the intermediate frequency signal also cancels out in the transformer coil 38 in Fig. 7. This in general results in an improved noise performance of the receiver of the order of 2-3 db.

Finally in connection with the properties of this hybrid junction it should be noted that the useful bandwidth to be expected will be of the order of 15-20%. This estimate is based on measurements made on a conventional 4 arm microstrip ring structure.

The manner of connecting the hybrid junction to the dipole feed is illustrated in Fig. 3. The dipole arms 9 and 10 are of large diameter to ensure a relatively broad band performance of say 10% of the mid band frequency. They are integral with the connecting arms 11 and 12 (being formed of the same copper rod or bar) which are in turn connected to the strip line conductors 2 and 6. It will be noted in this connection that the use of hybrid junction illustrated in Figs. 1 and 3 obviates the difficulties that otherwise occur if a balanced dipole is to be connected to an unbalanced line. This is an important advantage of the arrangement.

In order to ensure that the radiation pattern of the dipole feed is satisfactory when employed in the manner illustrated in Fig. 8, it is necessary to provide a reflecting surface, or parasitic dipole situated at a specified distance (between $\frac{1}{8}$ and $\frac{1}{4}$ wavelength according to the radiation pattern desired) behind the main dipole. This may be accomplished in the manner illustrated in Fig. 3, and in greater detail in Fig. 4, whereby the edge of the ground plane, the edge of the dielectric sheets and subsidiary strips 13 and 14 form the desired reflecting surface. The strip 13 may be connected to the ground plane by the folded piece of conductor 15 or by a series of wires. Other physical realizations which also depend on using the edge of the planar sheet as a parasitic dipole or reflector may be used if desired.

An alternative construction (not illustrated) may be used, in which the dipole assembly as a whole is printed in addition to the remaining components. In this case the ground plane must be cut back to the requisite distance in order to act as a parasitic reflecting surface.

It will be noted that the spacing of the conductors 11

and 12 is so chosen as to ensure a good match with the dipole (the impedance of which is approximately 80 ohms, in free space, but may be as low as 65 ohms in the presence of a parasitic reflector). Similarly the width of the strip conductors 2 and 6 in the vicinity of the junction with the dipole conductors 11 and 12 is so chosen in relation to the dielectric thickness that the impedance of each strip conductor line is equal to half the dipole impedance.

For this reason it may be convenient to choose W_1, W_2, W_3, W_4 in Fig. 1 so that a universal operating level of 30 to 40 ohms is maintained (with the exception of the ring conductor) throughout the planar transmission system. This, however, leads to an inconveniently wide form of strip conductor, and more important, presents difficulties with regard to matching if the arms 3, 4, and 5 are to be terminated in standard coaxial conductors and fittings of either 50 or 75 ohm impedance.

This problem may be overcome by tapering the conductors in an appropriate manner, at appropriate points, so as to allow a gradual non-reflecting change of impedance. In the receiver illustrated in Figs. 5 and 6 which has been built and tried out, the principal operating level is approximately 50 ohms (chosen on account of a large body of experimental results relating to lines of this impedance), and the conductors 2 and 6 are tapered so as to ensure a good match at the junction with conductors 11 and 12. A further taper is incorporated between arm 4 and the local oscillator input termination 24 in order to raise this impedance level to 75.

In Fig. 3 the arm 1 is "terminated" by a short-circuit indicated at 8, spaced from the junction ring 7 by a distance which is substantially equal to an odd number of quarter wavelengths, whereby the arm presents a high impedance at the operating frequency but also furnishes a D. C. return path for both the crystal rectifiers. It has been found in practice that a slight displacement from the theoretically correct position can be used as a means of tuning the circuit. The presence of arm 1 is not essential if other well known means are provided for completing the D. C. path for the crystals, as for example, by extending the arms 3 and 5 beyond the crystals, an additional odd number of quarter wavelengths and shortening the ends of the extensions.

Figs. 5 and 6 are respectively plan and elevation of a complete R. F. head which has been built for operation at 2000 mc./s. This design differs from that illustrated in Fig. 3 in that the reflecting edge is replaced by a circular conducting sheet 17 which also forms the front of a can (not shown) enclosing the whole of the unit. Also, the arm 1 has been moved from its position shown in Fig. 2, so that it is now located on a separate piece of microstrip line situated upside-down under the main sheet. In order to provide electrical continuity the two ground planes are soldered together and a connecting pin 18 joins the lower strip conductors 19 to the arm 1 of the hybrid junction on the upper sheet. This however, in no way effects the principle of operation.

The lines 3 and 5 in Fig. 5 are terminated by the two crystal holder assemblies 20 which project into the under part of the chassis of the intermediate frequency pre-amplifier 21, which here forms part of the complete assembly. The valves 22 of this pre-amplifier project upwards as shown. If desired this amplifier could be printed on the same microstrip panel after the manner indicated in the specification of British patent application No. 29511/53 (Grieg-Engelmann-Kostriza 165-16-5). However, in the present instance it was found more convenient to use an existing classical type of amplifier construction which was easily available. The power supplies to this pre-amplifier, and the I. F. output, are connected to the external circuit by means of the plug, sockets and cable 23, or by a plurality of such connections. The local oscillator input 25 is connected to the line 4 by means of the coaxial-to-microstrip transi-

tion 24 (of known type) via a variable attenuator 30 consisting of a suitably shaped piece of resistance card which can be slid over the line. The purpose of this attenuator is to permit adjustment of the crystal current to the desired value. Also incorporated is a monitoring circuit which includes a directional coupler 28 matched load 29, and a microstrip-to-coaxial transition 26 which connects via the coaxial cable 27 with the external circuit.

The crystal mixing circuit of this R. F. head is illustrated in Fig. 7, where 30 is the dielectric supporting material, 31 the ground plane, and 32 the strip conductor. The crystal 33 is supported in a holder of conventional type which consists of two parts 34 and 35 between which there is deliberately maintained a certain parasitic capacity 36. To provide the necessary D. C. return for the crystal a shunt post 37 is incorporated at an appropriate distance from the crystal holder, the distance being regulated, if so desired, as to minimise the crystal mismatch. In the present instance the post 37 is synonymous with the short-circuiting post 8 in Figs. 3 and 6. A similar arrangement exists for the other crystal mounting 40, here illustrated only in part. The outputs of the two crystals are coupled by the transformer coil 38 and are applied to the cathode of a conventional grounded-grid amplifier 39.

On test at 200 mc./s. little improvement could be obtained as a result of the judicious placing of suitable shunt susceptances so as to tune out any mismatch, thus indicating that the device was not very frequency sensitive and near optimum conditions pertained. A reasonably careful comparison with a coaxial receiver employing an identical pre-amplifier indicated that the noise figure of the planar receiver was within ± 2 db the same as that of the coaxial receiver.

In Fig. 8 is shown how the complete assembly enclosed in a cylindrical can 41 with a dome of "plastic" material 42 is mounted so that the dipole assembly is at the focus of the parabolic reflector 43. The diameter of the can, namely 5 inches is small compared to the diameter of the reflector namely 4 ft., and in any case the area obscured is not significantly greater than in the case of conventional horn feed.

It is to be noted that although the bandwidth is limited to 10-15% (principally on account of the frequency response of the dipole) the method of construction permits easy change of frequency. This is accomplished by printing a number of microstrip heads complete with dipole assembly, either of the form in Fig. 3, or alternatively as in Figs. 5 and 6, each appropriate to a particular frequency range.

These heads are much cheaper than the equivalent waveguide assembly, and much easier to exchange and reassemble in position, whilst retaining a common pre-amplifier and mounting assembly.

It should also be noted that the waveguide system described is not restricted to the particular form of planar construction known as microstrip. For example, it may also be accomplished in the type of construction illustrated in Fig. 9, sometimes referred to as a "sandwich" system, in which the strip conductor 44 is situated on the mid-plane between two ground planes 45 and 46. The dielectric material 48 may be homogeneous, or may consist of a plurality of materials of different dielectric constant. An example of the latter case is where the strip conductor 44 is supported or printed on a thin sheet of low-loss dielectric material situated in the mid plane, and the remaining space is air-filled.

While the principles of the invention have been de-

scribed above in connection with specific embodiments, and particular modification thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

What we claim is:

1. A waveguide hybrid junction comprising first and second strip conductors only, a planar dielectric sheet supporting said first conductor on one surface thereof and the second conductor on the opposite surface thereof, the spacing between said conductors being a small fraction of a wavelength at the mean operating frequency, said first conductor being a closed, circular waveguide loop having a mean perimeter equal to $6N$ quarter wavelengths at the mean operating frequency, six waveguide strip projections symmetrically disposed about said loop at equal spacings of a quarter wavelength, a dipole antenna having arms connected to two of said projections spaced apart one-half wavelength and having a width adapted to match the dipole impedance, balanced rectifier crystals in two other strip projections spaced apart a half wavelength, said waveguide junction comprising a pair of metallic reflector elements positioned to serve as a reflector system for said antenna and said elements being mounted on said second conductor and extending in a plane normal thereto.

2. A waveguide hybrid junction comprising first and second strip conductors only, a planar dielectric sheet supporting said first conductor on one surface thereof and the second conductor on the opposite surface thereof, the spacing between said conductors being a small fraction of a wavelength at the mean operating frequency, said first conductor being a closed, circular waveguide loop having a mean perimeter equal to $6N$ quarter wavelengths at the mean operating frequency, six waveguide strip projections symmetrically disposed about said loop at equal spacings of a quarter wavelength, a dipole antenna having arms connected to two of said projections spaced apart one-half wavelength and having a width adapted to match the dipole impedance, balanced rectifier crystals in two other strip projections spaced apart a half wavelength, further providing an additional waveguide section coupled at one end to said loop at a point separated by an odd number but greater than a quarter wavelength from said given point, said additional section including a direct current short-circuiting means located an odd number of quarter wavelengths from the coupled end of the section, and said short-circuiting means serving to provide a direct current return path for both said rectifiers.

References Cited in the file of this patent

UNITED STATES PATENTS

2,445,895	Tyrrell	July 27, 1948
2,587,590	Brewer	Mar. 4, 1952
2,637,813	Braden	May 5, 1953
2,639,325	Lewis	May 19, 1953
2,710,917	Himmel	June 14, 1955
2,749,521	Engelmann et al.	June 5, 1956
2,784,381	Budenbom	Mar. 5, 1957
2,789,210	Arnold	Apr. 16, 1957

OTHER REFERENCES

Microstrip Wiring Applied to Microwave Receivers, copyright 1953 by Federal Telecommunication Laboratories.
"Etched Sheets Serve As Microwave Components," Electronics, June 1952, pages 114 to 118.