Jan. 28, 1958 D. W. BLANCHER 2,821,708

COUPLING CONNECTION FOR SLOT ANTENNA

Filed June 1, 1954

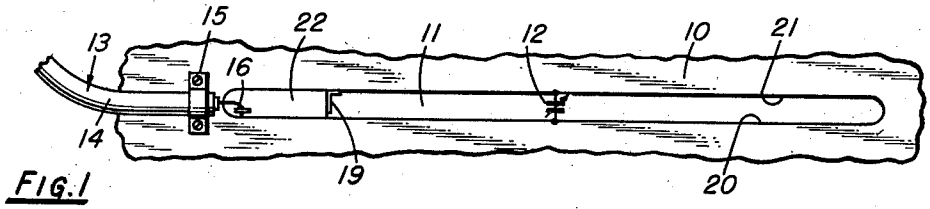

FIG. 1

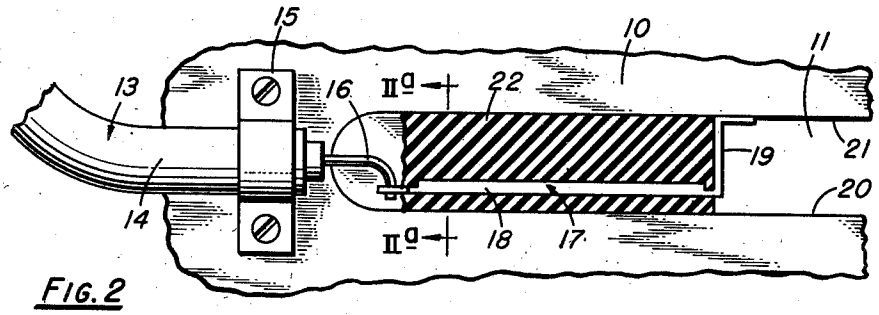

FIG. 2

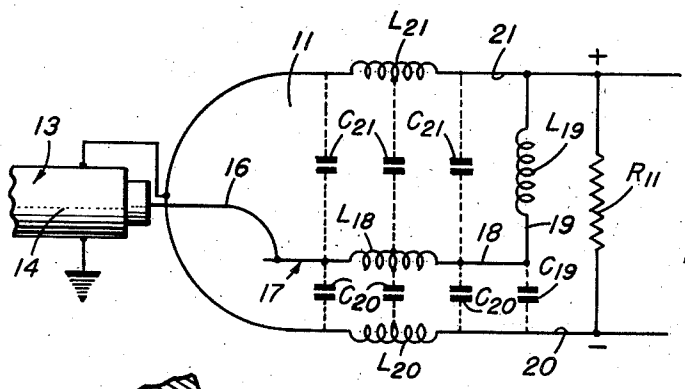

FIG. 3

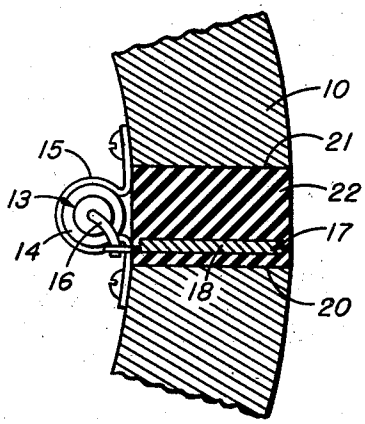

FIG. 2a

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United States Patent Office 2,821,708
Patented Jan. 28, 1958

2,821,708

COUPLING CONNECTION FOR SLOT ANTENNA

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Application June 1, 1954, Serial No. 433,725

5 Claims. (Cl. 343—767)

This invention relates to slot antennas and to apparatus for electrically coupling them to transmission lines.

An object of the invention is to provide a simple practicable and effective coupling structure for delivering electrical energy between a coaxial transmission line and a slot antenna.

Another object is to provide a very compact coupling structure capable of matching the impedance of a coaxial transmission line to that of a relatively high voltage point on a slot antenna.

Another object is to provide a simple and compact coupling structure for coupling a coaxial transmission line, which is unbalanced to ground, to a slot antenna that is balanced to ground.

Other more specific objects and features of the invention will appear in the description to follow.

Slot antennas have been known for many years and have obvious mechanical advantages over the conventional antennas in certain applications, such as on high-speed aircraft where the slot can be placed in the wall or skin of the aircraft without protruding structures that would alter the aerodynamics configuration of the craft. However, use of slot antennas in the VHF spectrum has been limited because of the problem of providing an efficient feed mechanism therefor. The problem is due in large measure to the difficulty of connecting an unbalanced transmission line, such as a coaxial cable, of relatively low impedance to a balanced slot antenna in such a way as to secure a good impedance match.

This problem is solved in a satisfactory manner in accordance with the present invention by employing as a coupling element between a coaxial cable and a slot antenna an L-shaped conductor positioned in the slot adjacent one end thereof with the long leg parallel to and closer to one wall of the slot than the other, and connected at its free end to the center (high potential) conductor of the coaxial line, the short leg of the conductor extending across the slot into electrical contact with the other wall of the slot. For reasons that will be more fully explained hereinafter, this exceedingly simple and compact coupling structure functions efficiently to transfer electric energy between the coaxial cable and the slot antenna.

In the drawing:

Fig. 1 is a face view of the inner side of a portion of a wall defining a slot antenna having a coupling structure in accordance with the invention.

Fig. 2 is an enlarged view of a portion of the wall at the feed end of the slot, showing a portion of the coupling structure in section.

Fig. 2*a* is a cross section in the plane A—A of Fig. 2.

Fig. 3 is a schematic diagram showing the equivalent electrical circuit of the coupling structure.

Referring first to Fig. 1, there is shown a metal wall **10** having a slot **11** therein and constituting the essential structure of a slot antenna. It is to be understood that the wall **10** can be of unlimited extent and constitute the outer wall or skin of an aircraft or the like. At the high

frequencies of operation of such devices, only that portion of the wall **10** closely adjacent the slot **11** has any effect on the currents that produce or are produced by an electric field across the slot **11**. When the antenna is used to transmit, a high-frequency electric field is produced in the slot **11** by potential developed between the opposite walls of the slot to cause radiation of electromagnetic energy in a well-known manner. Contrariwise, received electromagnetic waves produce an electric field between the walls of the slot, which produces a potential therebetween. For convenience, the invention will be described as applied to a transmitter.

For efficient operation, the slot **11** should have an electrical length of one-half wave at its frequency of operation. This result may be obtained either by making the slot exactly equal to a half wave length, or by making it shorter and providing auxiliary tuning, as by means of a condenser **12** connected across the slot at its midpoint. Either type of slot antenna may be employed with the present invention, although the latter is particularly useful with tuned slots of length less than one-half wave in physical dimension because of the increased difficulty of feeding such slots by other known methods.

Referring now to Fig. 2, there is shown a coaxial cable **13** having an outer conductor **14** which is terminated at the left end of the slot **11** and is mechanically attached to the wall **10** by a clamp **15**. The cable **13** has an inner conductor **16** which is insulated from the outer conductor **14** and will sometimes be referred to as the high potential conductor, since, as is customary in a coaxial cable, the outer conductor **14** is at ground potential. This conductor **16** is extended into the slot **11** and connected to the free end of the long leg **18** of an L-shaped coupling conductor **17**. The leg **18** is a flat strip and extends parallel to the sides **20** and **21** of the slot **11** and substantially closer to one wall **20** than to the other wall **21**. The short leg **19** of the L-shaped conductor **17** extends transversely across the slot away from the wall **20** and into contact with the wall **21** to which it is bonded.

To provide mechanical support for the conductor **16** and the member **17**, the portion of the slot **11** in which the structure **17** is positioned may be filled with a suitable solid dielectric material **22** in which the conductor **17** is imbedded. This dielectric material **22** preferably has a higher dielectric value than air, so as to increase the capacity between the long leg **18** and the sides **20** and **21** of the slot.

The equivalent circuit of the arrangement of Fig. 2 is shown in Fig. 3, in which the side **20** of the slot is shown as a conductor having distributed inductance L_{20}, the side **21** of the slot is shown as a conductor having distributed inductance L_{21}, and the long leg **18** of the conductor **17** is shown as a conductor having distributed inductance L_{18}. The distributed capacity between the leg **18** and the side wall **20** is illustrated as capacities C_{20}, and C_{19}, and the distributed capacity between the leg **18** and the side wall **20** is represented as capacities C_{21}. The short leg **19** is represented as a conductor having distributed inductance L_{19}. The radiation resistance of the antenna as seen by the coupling mechanism is represented by a resistor R_{11} connected between the conductors **20** and **21**. It will be observed that the left ends of the conductors **20** and **21** are shown connected to the ground conductor **14** of the coaxial cable, so that they are at ground potential at that point.

It will be observed from inspection of Fig. 3 that the lines **18** and **21** constitute one transmission line having series inductance L_{18} and L_{21} and distributed capacity C_{21} and terminating in the inductance L_{19}, whereas the conductor **18** and the conductor **20** define a transmission line containing series inductance L_{18} and L_{20} and shunt capacity C_{20} and terminated by the capacity C_{19}.

It is to be noted that because of the closer positioning of the leg **18** (Fig. 2) to the wall **20** than to the wall **21**, it has a substantially greater capacity to wall **20** than to wall **21**. In Fig. 3, the capacity C_{19} represents the difference between the total capacity between conductor **17** and slot wall **20** and the capacity between conductor **17** and the slot wall **21**. The two transmission lines recited above are fed in parallel from the coaxial cable **13**. The leg **18** and the side walls **20** and **21** of the slot define segments of uniform transmission lines between the end of the slot and the short leg **19** of member **17**, but at that point they are terminated by impedances of opposite reactance. Thus, the segment consisting of the conductor **18** and the side walls **21** are terminated by the inductance L_{19}, whereas the segment consisting of the conductor **18** and the slot wall **20** are terminated by the capacity C_{19}. The potential across the inductance L_{19} leads the current in the circuit by approximately 90°, and the potential across the capacity C_{19} lags the current in the circuit by approximately 90°, so that the alternating voltages at the extremities of inductance L_{19} and capacity C_{19} are approximately 180° out of phase. Hence, the two sides of the slot are excited with potentials of opposite polarity and in balanced condition with respect to ground.

Inasmuch as the long section **18** of the conductor **17** and the sides **20** and **21** of the slot form segments of transmission lines that are terminated at their right ends in impedances that are different from their surge impedances, the segments act as voltage transformers, and the impedance of the transmission line rises at the same rate as the impedance rises between the sides of the slot. Therefore, the coupling element provides an automatic impedance match to the slot.

In a typical installation for operation at 225 megacycles, the structure shown in Figs. 1 and 2 may have the following values:

Length of slot **11**—in—	8
Width of slot **11**—in—	¼
Approximate value of condenser **12**—mmf—	17
Length of leg **18**—in—	1
Width of leg **18**—in—	⅜
Area of leg **18** juxtaposed to the sides of slot—sq. in—	⅜
Spacing of leg **18** from side **20**—in—	1/32
Spacing of leg **18** from side **21**—in—	7/32
Dielectric coefficient of dielectric **22**	2.1
Surge impedance of coaxial cable **13**—ohm—	50

In such an installation, the radiation efficiency was found to be approximately equivalent to that obtainable from the maximum lobe of a half-wave dipole.

The length of the coupling conductor **18** is not critical. However, it does have to satisfy a minimum condition, that is the condition of matching from a low impedance to the relatively high slot impedance. An optimum length would be that which satisfies the matching requirements. However, due to the fact that the impedance of a shortened slot, i. e., one less than half-wave length and tuned by added capacity such as the condenser **12**, rises rather abruptly a short distance from the end and thereafter levels off somewhat, the length of the matching conductor becoming non-critical after the high impedance region of the slot is reached. The length of the matching conductor is affected to some degree by the dielectric material between the slot and conductor (increase of dielectric constant appears to allow shorter conductors to be used). A practical ratio of matching conductor length to slot length appears to be 1:8. The ratio of conductor to slot length may vary if the slot width and depth are changed.

Although for the purpose of explaining the invention, a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art, and I do not desire to be limited to the exact details shown and described.

I claim:

1. In combination: a slot antenna consisting of a conductive wall member defining an elongated slot closed at its ends and having juxtaposed side walls; a transmission line terminating adjacent one end of said slot and having a grounded conductor connected to said wall member, and having a high potential conductor; and a coupling conductor in said slot electrically connecting said high potential conductor to one wall of said slot at a point spaced from said one end thereof, said coupling conductor comprising a longitudinal section having one end adjacent said one end of said slot and connected to said high potential conductor and having a transverse section extending from the other end of said longitudinal section to said one wall of said slot, said longitudinal section being positioned closer to the other wall than to said one wall, whereby its capactive coupling to said other wall is greater than its capacitive coupling to said one wall.

2. Apparatus according to claim 1 including dielectric material of higher dielectric constant than air interposed between said longitudinal section and said other wall.

3. Apparatus according to claim 1 in which said longitudinal section extends longitudinally parallel to said walls.

4. Apparatus according to claim 1 in which said longitudinal section is of ribbon form extending laterally parallel to said walls.

5. Apparatus according to claim 4 in which the width of said longitudinal section is substantially the same as the width of the walls of the slot.

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