INTEGRATED AIRFRAME BULKHEAD AND CAVITY ANTENNA

INVENTORS.
John E. Brunner
By Alton E. Hallum
Wood, Herron & Evans
ATTORNEYS
INTEGRATED AIRFRAME BULKHEAD AND CAVITY ANTENNA

John E. Brunner, Middletown, and Alton Z. Hallum, Cleveland, Ohio, assignors to Aeronec Manufacturing Corporation, Middletown, Ohio, a corporation of Ohio

Filed Oct. 11, 1962, Ser. No. 229,819

5 Claims. (Cl. 343—708)

This invention relates to an antenna and is particularly directed at a tracking antenna system for a target missile, although the several structural features of the invention are not necessarily limited to that environment.

A target missile is a small, comparatively inexpensive device which is fired into the atmosphere or even into space, is tracked by interrogating radar and is in turn fired at by anti-missile missiles. The objective of the use of a target missile is to simulate the conditions of an intercontinental ballistics missile of comparatively huge proportions so as to prepare for defense against an attack through ICBMs. The expense and hazards attending the launching of ICBMs for target practice prohibits the use of the ICBM and requires the use of a target missile which simulates the ICBM.

Because of the small size of the target missile, in the absence of means for simulating the size of the ICBM, the interrogating radar would see a device which does not resemble an ICBM, and thus, there would be an inability to practice under authentic conditions. It is therefore a requirement in a target missile to provide an echo enhancing system which receives a signal from interrogating radar, amplifies the signal and returns an augmented (amplified) signal to the interrogating radar to be a signal reflected from an object the size of an ICBM. To create these conditions, the echo enhancing system-antenna must produce, among other characteristics, omnidirectional circularly polarized pattern.

It is another requirement of a target missile that the components thereof be rugged in themselves and be mounted in the missile in such a manner as to withstand extraordinary acceleration and deceleration forces so that the forces attending the operation of the missile will not destroy the missile's utility and so that the missile can be re-used. In operation, the missile is propelled toward space, and at some point in its trajectory the forward portion of the missile is separated from its booster section. Thereafter, a parachute is ejected from the missile permitting the missile to drift toward the earth. In order to avoid the booster section fouling the parachute the forward portion of the missile must be separated from the booster section with considerable force to drive the two sections apart. The force of the separation must be so great that the components of the missile are subjected to a 100-G acceleration force and so that the missile can be re-used.

The invention has as its basic component an integrated strip line antenna which is located in a cavity section of the target missile. The cavity section is formed in the body of the target missile and is separated from the forward section of the missile by a bulkhead. The target missile is a small, comparatively inexpensive device which is fired into the atmosphere or even into space, is tracked by interrogating radar and is in turn fired at by anti-missile missiles. The objective of the use of a target missile is to simulate the conditions of an intercontinental ballistics missile of comparatively huge proportions so as to prepare for defense against an attack through ICBMs. The expense and hazards attending the launching of ICBMs for target practice prohibits the use of the ICBM and requires the use of a target missile which simulates the ICBM.

The invention provides a means for mounting the radiating elements in radial bores in the bulkhead to reduce the requirement of holding close tolerances in the formation of the radial bores in the bulkhead. This mounting means includes the use of a conductive sleeve on the rigid coaxial transmission line, the sleeve not only properly orienting the radiating element but additionally, being positionable on the transmission line to effect proper tuning of the slot balun.

The invention provides a means for mounting the radiating elements in a target missile, the radiating elements being joined centrally to the bulkhead and having a transmission line projecting from one side of the bulkhead, and further providing an easily accessible shorting plunger on the opposite side of the bulkhead to provide final factory tuning of the antenna system. It can be seen that, by providing an integrated antenna system as described above wherein a bulkhead forming a part of the system is a structural member which joins the forward portion and the rearward portion of the target missile, it is possible to manufacture the antenna system as a complete subassembly and to perform complete electrical tests of the assembly prior to mounting it in association with the remainder of the missile structure. Thus, considerable convenience in manufacturing operations is attained.

These and other objectives of the invention will become more readily apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIGURE 1 is an elevational view of the target missile with which the invention is employed.

FIGURE 2 is an enlarged fragmentary elevational view of the antenna mounted in association with the forward and rearward portions of the missile.

FIGURE 3 is an elevational view taken in the direction of lines 3—3 of FIGURE 2.

FIGURE 4 is a cross-sectional view taken along lines 4—4 of FIGURE 3.

FIGURE 5 is a cross-sectional view taken along lines 5—5 of FIGURE 4.

FIGURE 6 is a cross-sectional view taken along lines 6—6 of FIGURE 5.

FIGURE 7 is an elevational view partly in section of a radiating element and its rigid coaxial transmission line.

Referring to the drawings, a missile of the type to which the invention is directed is shown in FIGURE 1. The missile has a forward or nose portion 10 and a rearward or tail portion 11. The two portions or sections 10 and 11 are joined together by the antenna bulkhead of the present invention and are joined together by the antenna bulkhead of the present invention indicated at 12. The rearward section may be considered to be divided into two parts, the booster section 14 which is ejected from the missile during flight and the parachute section 15 in which the strip line antenna described in co-pending application Serial No. 220,770, filed August 31, 1962, is located.
As shown in FIGURES 2 and 3, the antenna 12 is secured by circumferentially spaced screws 16 to the forward portion 10 and to the rearward portion 11. Physically, the major element of the antenna is a casting forming a transverse bulkhead 18, the bulkhead having an annular flange 19, the flange being secured to the airframe or skin of the forward and rearward missile sections.

Spaced in quadrature about the annular flange 19 are cavities 20 formed integrally in the casting. Each cavity has a dipole radiating element 21 mounted in it, the radiating element 21 being covered by a radome 22. The radome is a plastic member which is translucent to electromagnetic waves and which has a physical characteristic which permits it to withstand very high re-entry temperatures. As best shown in FIGURE 4, each radome is recessed as at 17 to increase the spacing of the radome from the dipole, thereby reducing the electrical loading effect of the radome on the dipole. The cavity 20 may include a conductive lining 23 (FIGURE 4) which is precisely made so that its internal dimensions satisfy critical electrical requirements.

Fixed to the bulkhead and projecting parallel to the axis of the missile are four stand-offs, or posts 24 by which an augmenter, shown in broken lines at 25, is mounted to the bulkhead. The stand-offs 24 as well as the bulkhead 18 form a heat sink for the heat developed by the augmenter and thus maintain the temperature of the augmenter to a satisfactorily low temperature. Additionally, the posts 24 form the sole mounting of the augmenter in the missile. Since the posts are fixed to the bulkhead 18, the weight of the augmenter 25 is transferred to the missile air frame by means of the bulkhead, the annular flange 19 distributing the weight uniformly around the circumference of the airframe.

The radiating elements 21 are shown in detail in FIGURE 7. Each comprises a pair of dipole wings 29 and 30 fixed respectively to one of the two legs 31 of the slot balun portion 32 of the radiating element. The slot balun portion of the radiating element is formed by the outer end portion of a rigid coaxial transmission line 33. The transmission line 33 has a rigid outer metallic conductor 34, a copper inner conductor 35, the two conductors being separated by a dielectric such as Teflon (tetrafluoroethylene) 36. The center conductor 35 is connected by a set screw 37 to the slot balun leg 31 to which the dipole wing 29 is attached. A sleeve 38 is fixed to the outer conductor 34 and overlaps a portion of the balun slot 39.

Except for the sleeve 38, the dipole structure thus described is known. In operation, the dipole wing 29 is directly driven by means of the center conductor 35. A capacitive couple created by the slot balun drives the opposite dipole wing 30. Insofar as possible, the capacitive reactance of the couple should be balanced out by the inductive reactance of the balun legs. The inductance created by the slot balun is a function of the length of the slot 39 and can be varied by reducing the length of the slot. The impedance of the radiating element is also affected by such factors as the depth of the dipole in the cavity, the distance to the radome and the angle at which the dipole is set. By properly selecting the longitudinal position of the sleeve 38 with respect to the balun slot 39, the capacitive and inductive reactances of the radiating element can be balanced.

In practice, in the initial design of the antenna, the radiating element is placed in the cavity 20, enclosed by the radome and tested. If it is not properly tuned, sleeve 38 is adjusted and tested again. This process continues until optimum tuning is effected. In this manner the proper position of sleeve 38 is determined and thereafter can be duplicated.

As shown in FIG. 4, each radiating element and its associated rigid coaxial transmission line is mounted in a radial bore 45 formed in the bulkhead 18. The inside diameter of each bore 45 is substantially the same as the outside diameter of sleeve 38. There is a considerable clearance between the wall of the bore 45 and the surface of the outer conductor 34 for reasons which will be set forth below. The sleeve 38, which at the time of installation is fixed on the outer conductor 34, is secured to the bore 45 within bore 45 by a set screw 46.

The construction of the antenna at the inner ends of the radiating elements is best illustrated in FIG. 5. As shown in FIG. 5, a sleeve 47 is tightly fitted within a bore 48 in the bulkhead casting by freezing the sleeve, inserting it in the bore 48 and permitting it to expand. The sleeve 47 is co-axial with the missile axis. A tapered center conductor or impedance transformer 49 is mounted within the sleeve 47 and is separated from it by a dielectric sleeve of Teflon 50. The sleeve 47 has four holes 51 which are bored to form shoulders 52, the holes 51 being aligned with the bores 45. The radiating element has its outer conductor 34, inner conductor 35 and dielectric 36 cut to precise lengths so that during assembly the radiating element is slipped into the bore 45 and the inner end of the outer conductor 34 bottoms on the shoulder 52. The distance between the shoulder 52 and the bottom of cavity 29 is precisely maintained in order to assure the precise radial positioning of the dipole wings 29 and 30 to meet the electrical requirements of the system.

By employing a large bore 45 with a precisely located hole 51 and shoulder 52, the tolerances required for proper electrical operation can be conveniently maintained. A bore such as bore 45 which may have a length of about 24 inches is difficult to form because of the tendency of the boring tool to "walk" or fail to move in a straight line. Any variation in the desired line would adversely affect the electrical characteristics of the antenna system. By mounting the radiating element at two precisely locatable points, that is at the outer end portion by means of the sleeve 38 and at the inner end by means of the hole 51 and shoulder 52, the necessary alignment of the radiating element is attained.

The center conductors 35 meet at the center of the tapered center conductor 49. The impedance of the transmission lines going into the junction is 50 ohms but is only 12½ ohms going out of the junction to the augmenter. By employing a tapered center conductor 49, the impedance can be transformed to 50 ohms and thus maintain the impedance match of the system.

The inner ends of the center conductors 35 are secured to the tapered center conductor 49 by a plug 54 which is annularly shouldered at its inner end. The plug is threaded in an internally threaded bore 56. The annular shoulder 55 eliminates the necessity of bottoming the tap hole. The other end 87 of the tapered center conductor is connected to a TNC connector 58 and, by means of further coaxial transmission lines, is connected to the augmenter 25.

In the side of the bulkhead opposite the augmenter a shorting plunger 60 is secured to the bulkhead with a cylindrical portion 61 projecting into the recess between the tapered center conductor 49 and the sleeve 47. The application of the shorting plunger is one of the last steps in the manufacture of the antenna and the shorting plunger effects the final tuning. In fact, other than the angular orientation of the dipole wings during assembly, the application of the shorting plunger represents the only tuning adjustment on the antenna.

In the absence of the shorting plunger, it might appear from the augmenter that there are five radiating elements, namely the four dipole elements and an imperfect radiator in the form of the projecting end portion of the tapered center conductor. Ideally, the area axially beyond the junction of the radiating elements 21 should appear to be an open circuit so as to be sure that there is no wave reflected back to the augmenter. Any wave reflected back to the augmenter will raise the voltage standing wave ratio above a required maximum. If the circuit is otherwise properly tuned, then the apparent open circuit con-
dution can be effected if the distance between the center conductors 35 and the inner extremity 62 of the cylindrical portion 61 is a quarter wave length. Under such conditions, the dimensions of the shorting plunger could be standardized and the mounting of it to the bulkhead would complete the final tuning of the antenna. However, the ideal conditions cannot be maintained because of the tolerance requirements of manufacture. If the system is not properly tuned, that is, if there is a little reactance in the system, final tuning can be effected by increasing or decreasing the distance between the shorting plunger and the center conductors 35.

More specifically, in the final assembly, the bulkhead is mounted in special tuning apparatus and with the wave pattern appearing on an oscilloscope the shorting plunger is introduced. By observing the oscilloscope, the position of the shorting plunger for optimum tuning can be observed. This position is noted, the shorting plunger is cut to provide that proper position and it is re-inserted and secured into position by means of screws 63.

In the manufacture of the antenna the bulkheads are cast substantially as shown. It may or not be necessary to employ a cavity liner 23 depending upon the ability to cast the cavity with the required sharp corners and within the desired tolerances. The casting is formed with the bores 45 either during the casting or by subsequent drilling. The sleeve 47 housing the taped center conductor and the dielectric 50 is inserted and the additional boring to form the hole 51 with the shoulder 52 is performed. A hole is also bored through the dielectric and the tapered center conductor to permit the passage of the center conductor 35.

The dipole elements have previously been manufactured to precise lengths and are inserted in the bores 45 with the inner end of the outer conductor 34 bottoming on the shoulder 52. Set screws 46 are tightened to secure the elements in the bulkhead. As the set screws 46 are tightened, the dipole wings are held in the proper angular position within the cavities 20.

The plug 54 is tightened against the engaging inner ends of the center conductors 35 to connect them to the tapered center conductor 49.

The bulkhead is then mounted in test apparatus to examine the band pass characteristics. The shorting plunger is applied and cut to the proper length for optimum band pass as described above and then screwed to the bulkhead in its fixed position. After the shorting plunger has been permanently applied, a pin passing through holes 65 adjacent the shorting plunger can be inserted. The pin holds the vent line to the parachute.

The augmenter 25 is secured to the stand-offs, or posts, 24 and is connected to the coaxial transmission system or, more particularly, to the right angle TNC coaxial connection 58.

During the final assembly of the missile, the bulkhead with the augmenter attached is joined to the forward and rearward sections of the missile and is ready for operation.

The antenna described above can produce, for example, an omnidirectional circularly polarized pattern at 5900 megacycles. The band pass is 250 megacycles with a maximum VSWR of 1.5. It should be understood, of course, that the device described is applicable to a wide spectrum of frequencies.

We claim:

1. In a missile having a forward section and a rearward section, an antenna assembly joining said two sections, said antenna assembly comprising:

   a. a transverse bulkhead including an annular flange having an outside diameter equal to the outside diameter of said missile sections, means joining said forward and rearward sections to said annular flange,
   a. a plurality of dipole radiating elements circumferentially spaced about said flange and having their outermost extremities within the cylindrical plane of said annular flange, a radome covering each said element and having its outer surface lying in the cylindrical plane of said annular flange, a plurality of posts projecting longitudinally from said bulkhead, an augmenter secured to and supported only by said posts, and coaxial transmission means connecting said radiating elements to said augmenter.

2. In a missile having a forward section and a rearward section, an antenna assembly joining said two sections, said antenna assembly comprising:

   a. a transverse bulkhead including an annular flange having an outside diameter equal to the outside diameter of said missile sections, means joining said forward and rearward sections to said annular flange,
   a. a plurality of dipole radiating elements circumferentially spaced about said flange and having their outermost extremities within the cylindrical plane of said annular flange, a plurality of posts projecting longitudinally from said bulkhead, electrical circuit means secured to and supported only by said posts, and coaxial transmission means connecting said radiating elements to said electric circuit means.

3. In a missile having a forward section and a rearward section, an antenna assembly joining said two sections, said antenna assembly comprising:

   a. a transverse bulkhead including an annular flange having an outside diameter equal to the outside diameter of said missile sections, means joining said forward and rearward sections to said annular flange,
   a. a plurality of radial bores extending inwardly from said annular flange through said transverse bulkhead, means forming a shoulder at the inner end of each bore, and a dipole radiating element having a rigid coaxial transmission line including an outer conductor extending into each said radial bore and secured thereto with the inner end of said conductor seated on said shoulder.

4. In a missile having a forward section and a rearward section, an antenna assembly joining said two sections, said antenna assembly comprising:

   a. a transverse bulkhead including an annular flange having an outside diameter equal to the outside diameter of said missile sections, means joining said forward and rearward sections to said annular flange,
   a. a plurality of dipole radiating elements circumferentially spaced about said flange, coaxial transmission means connected to each dipole and passing radially through said bulkhead and projecting axially from one side of said bulkhead, and a shorting plunger mounted on the opposite side and centrally of said bulkhead for tuning said transmission means.

5. An antenna assembly comprising:

   a. a transverse bulkhead,
   a. a plurality of radial bores passing from the outer surface of said bulkhead to the center thereof, a plurality of dipole radiating elements circumferentially spaced about said bulkhead and having rigid coaxial transmission lines of substantially smaller outer dimension than the inner dimension of said bores and disposed within said bores, each transmission line including a slot balun terminated at its radially inner end by a sleeve, said sleeve being secured in said bore to fix the outer
end portion of said rigid transmission line in said bulkhead, and
means fixing the inner end of each said transmission line to said bulkhead.

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HERMAN KARL SAALBACH, Primary Examiner.

ELI LIEBERMAN, Examiner.