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Ryken et al.

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(54) **GPS AND TELEMETRY MICROSTRIP ANTENNA FOR USE ON PROJECTILES**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **H01Q 1/36**

(52) **U.S. Cl.** .... **343/700 MS**; 343/705; 343/846

(58) **Field of Search** .... 343/700 MS, 725, 343/705, 708, 829, 846, 853; 333/134; 342/354, 371; H01Q 1/36

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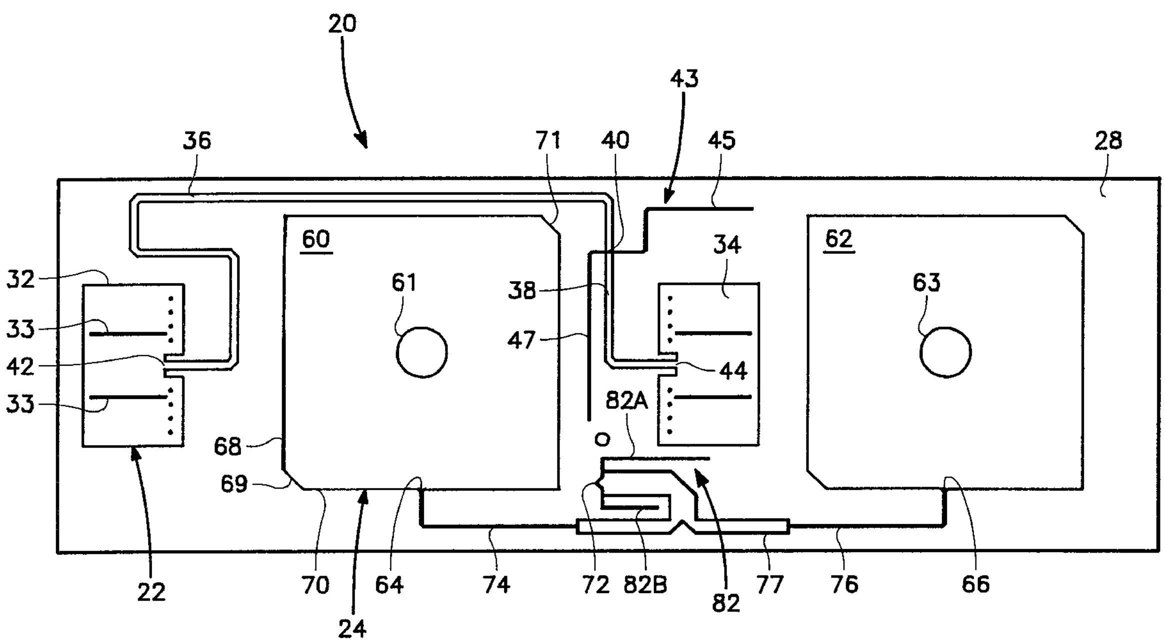
(57) **ABSTRACT**

A microstrip antenna system having a GPS antenna for receiving GPS data and a telemetry antenna for transmitting telemetry data mounted on a dielectric substrate. The microstrip antenna system is designed for use on small diameter airborne projectiles which have a diameter of about 2.75 inches. A pair of band stop filters are integrated into the antenna system to isolate the transmitted telemetry signal from the received GPS signal.

20 Claims, 6 Drawing Sheets



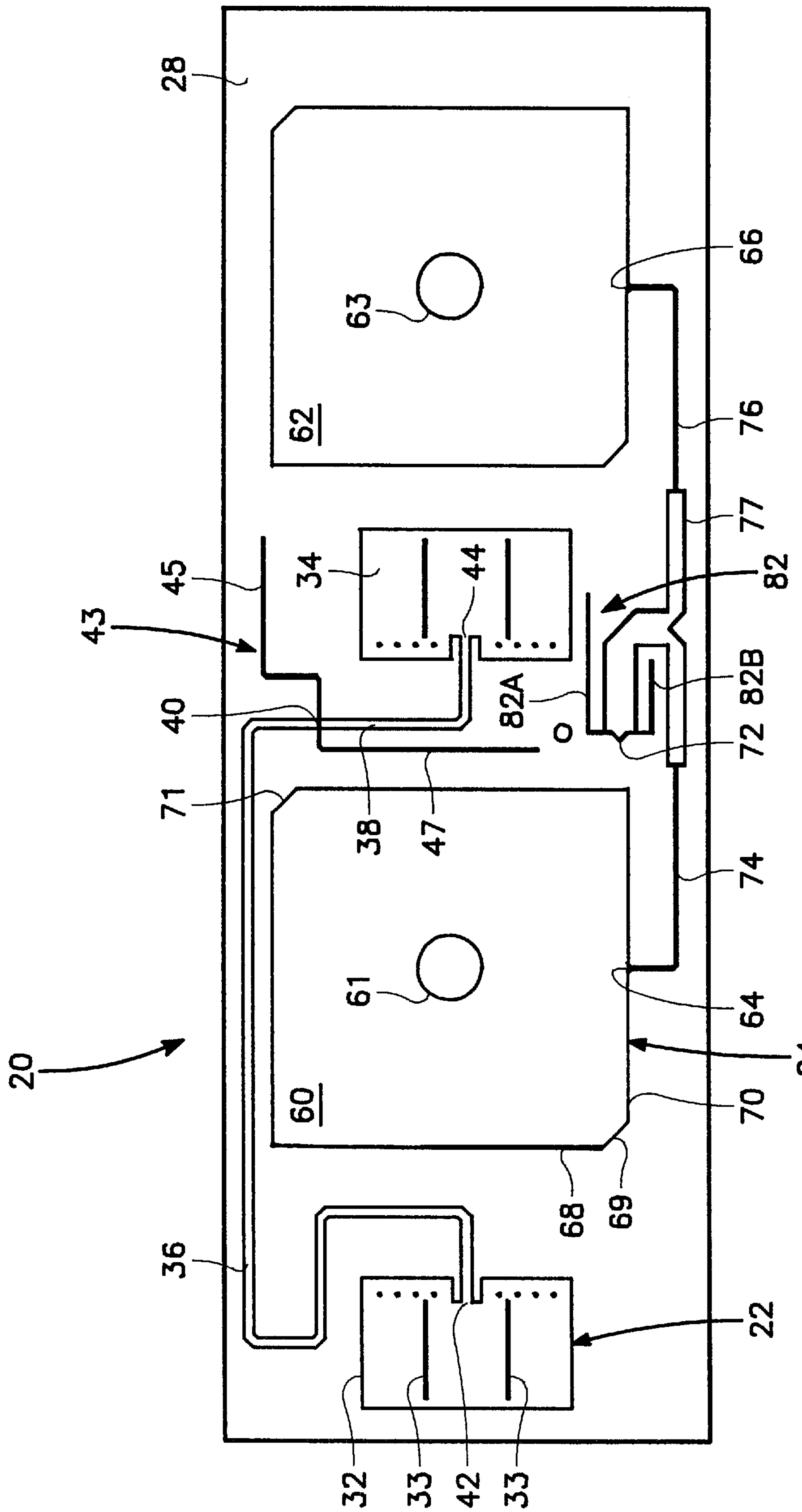

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FIG. 1

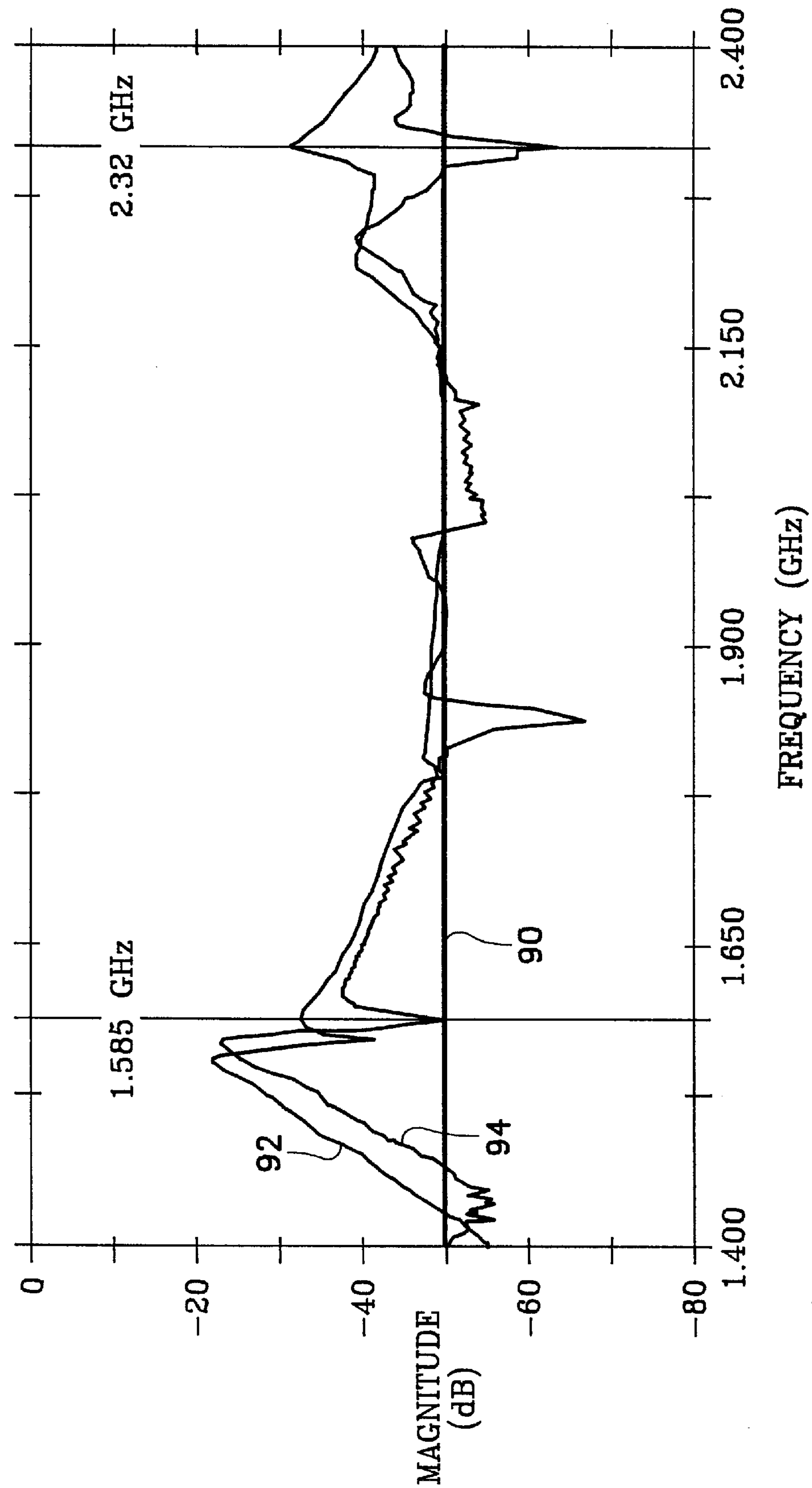
0
-20
-40
-60
-80
MAGNITUDE
(dB)
1.400
1.650
1.900
2.150
2.400
FREQUENCY (GHz)
1.585 GHz
2.32 GHz
90
92
94

FIG. 2

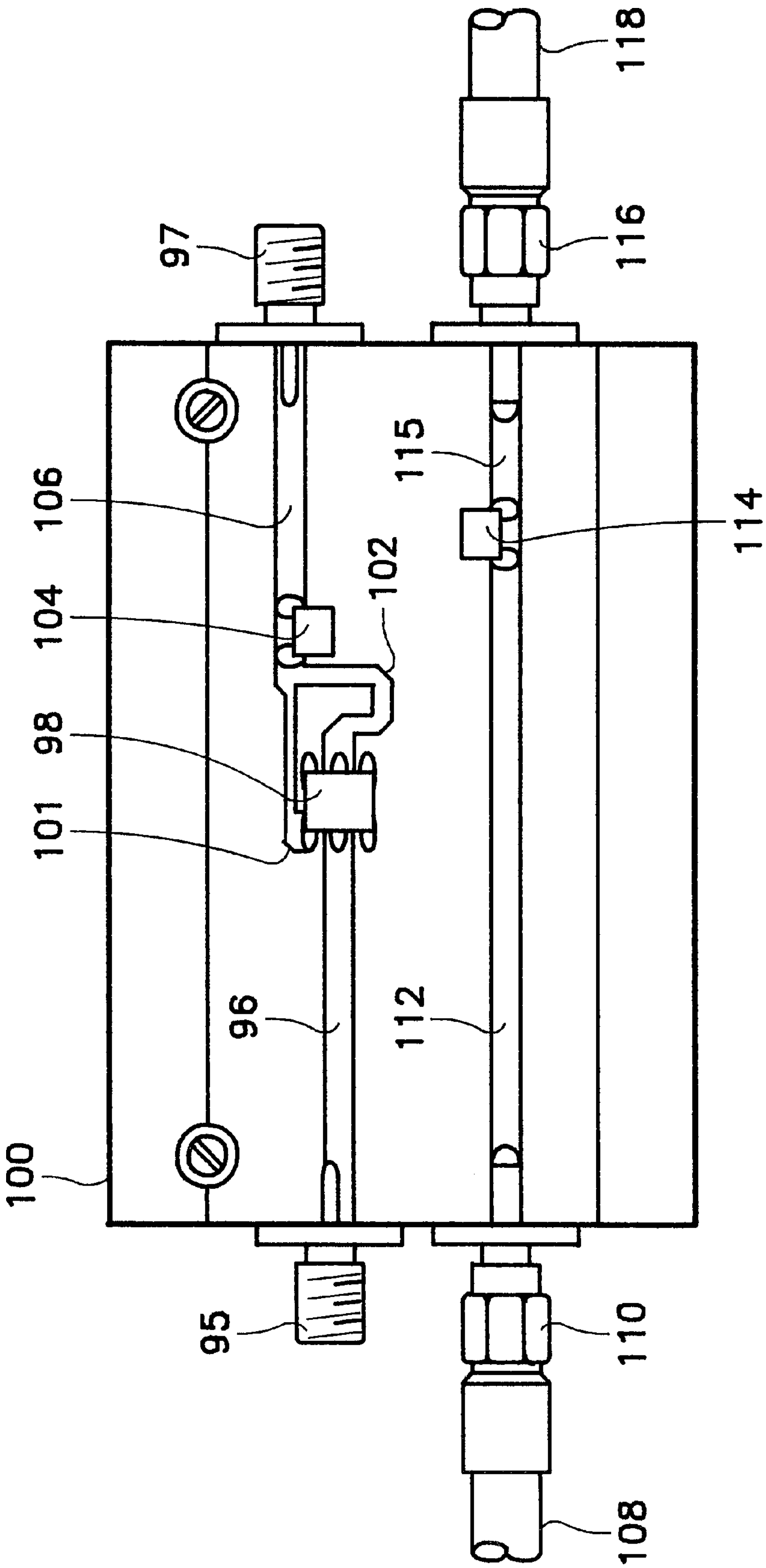

FIG. 3

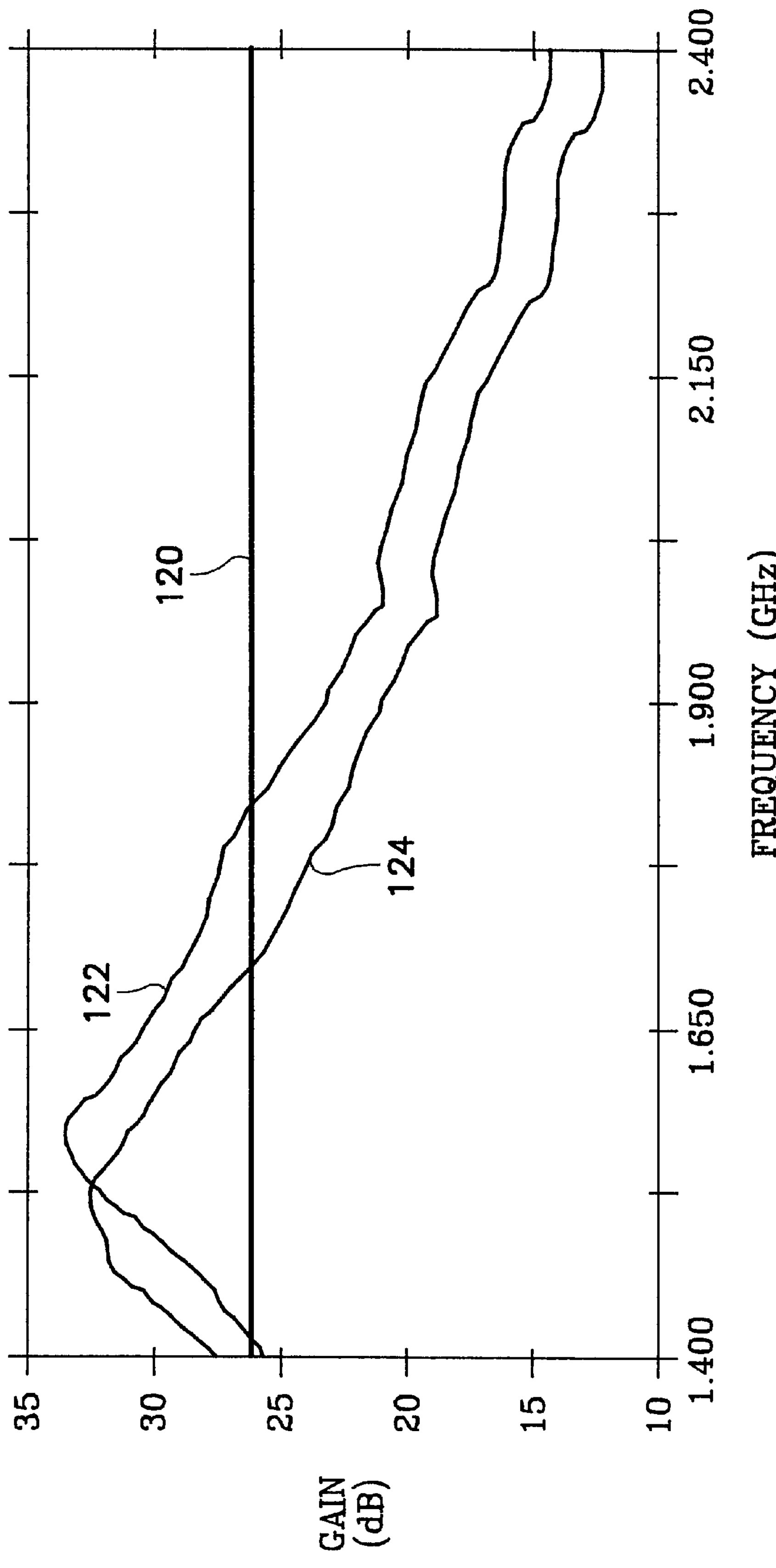
120
122
124
35
30
25
20
15
10
GAIN
(dB)
1.400
1.650
1.900
2.150
2.400
FREQUENCY (GHz)

FIG. 4

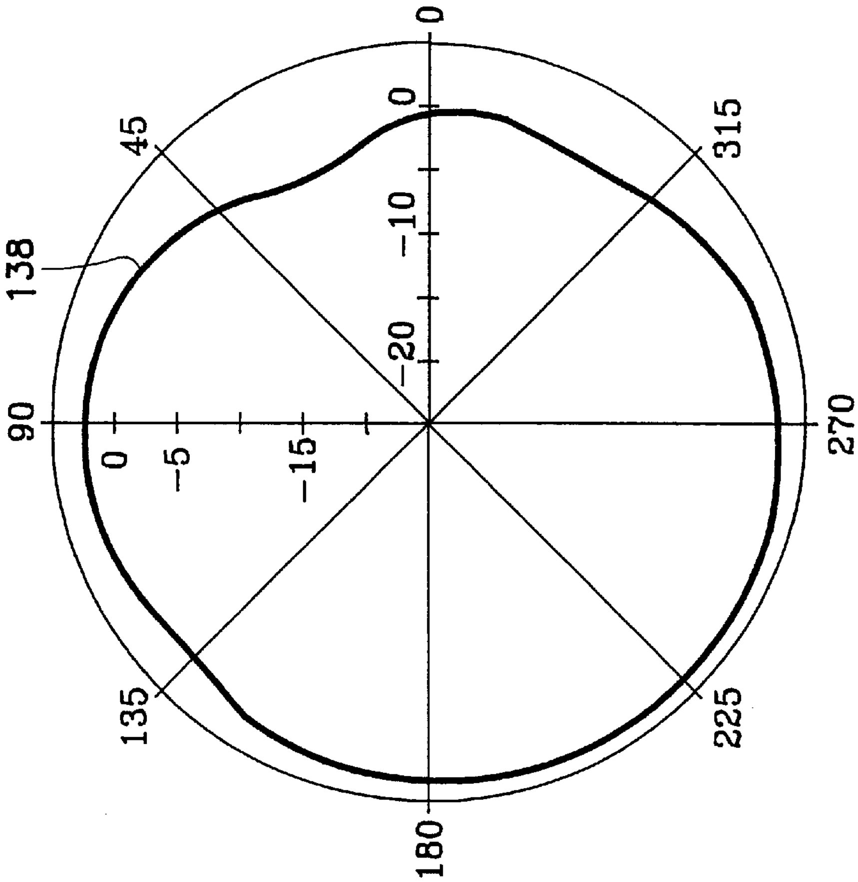

FIG. 5B

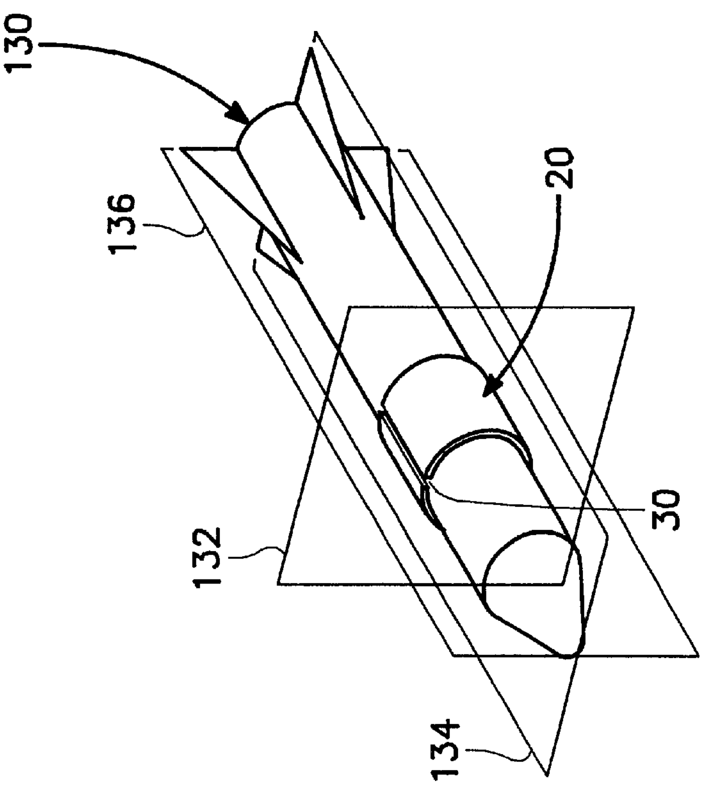

FIG. 5A

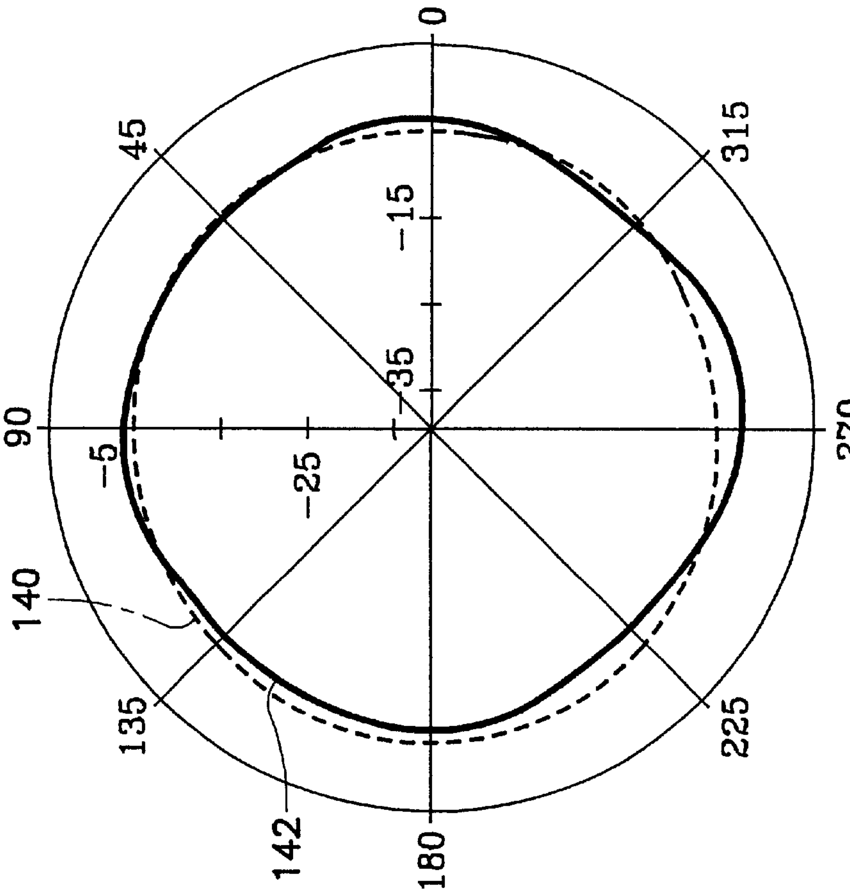

FIG. 6B

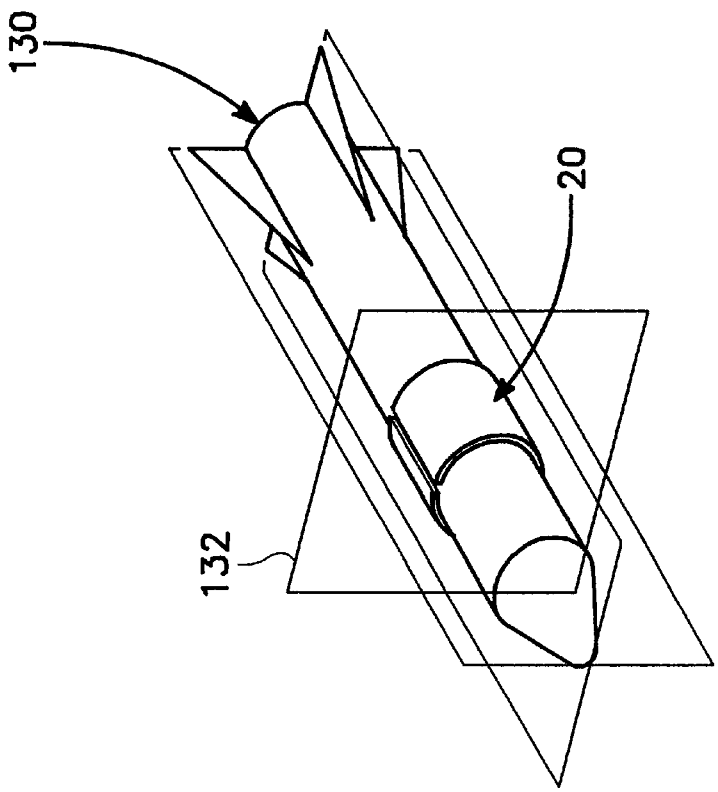

FIG. 6A

GPS AND TELEMETRY MICROSTRIP ANTENNA FOR USE ON PROJECTILES

This application is a continuation-in-part of U.S. patent application, Ser. No. 10/039,939, filed Oct. 19, 2001 now U.S. Pat. No. 6,466,172.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to an antenna for use on a missile or the like. More specifically, the present invention relates to a microstrip antenna which includes a GPS antenna for receiving GPS data and a telemetry antenna for transmitting telemetry data and which is adapted for use on small diameter devices such as a missile.

2. Description of the Prior Art

In the past military aircraft and weapons systems such as airplanes, target drones, pods and missiles have included flight termination and beacon tracking antenna to monitor performance during test flights. For example, a missile under test will always have an antenna which is generally surface mounted to transmit telemetry data to a ground station. The ground station then performs an analysis of the telemetry data from the missile to determine its performance during flight while tracking a target.

U.S. Pat. No. 4,356,492 is an example of a prior art microstrip antenna which is adapted for use on a missile as a wrap around band to a missile body without interfering with the aerodynamic design of the missile. U.S. Pat. No. 4,356,492 teaches a plurality of separate radiating elements which operate at widely separated frequencies from a single common input point. The common input point is fed at all the desired frequencies from a single transmission feed line.

With the emerging use of the Global Positioning System (GPS) for tracking purposes, there is a need to include GPS within the instrumentation package for a missile and target drone to accurately measure flight performance. GPS data is extremely accurate and thus allows for a thorough analysis of the missile's performance as well as the target drone's performance in flight while the missile tracks the target drone on a course to intercept the target drone.

The use of satellite provided GPS data to monitor the position of a missile and a drone target in flight will require that an antenna for receiving the GPS data be included in the instrumentation package. The receiving antenna should preferably be mounted on the same dielectric substrate as the transmitting antenna so that the antenna assembly can be applied readily as a wrap around band to the missile body without interfering with the aerodynamic design of the missile. Similarly, the antenna assembly which would include a GPS data receiving antenna and telemetry data transmitting antenna configured as a wrap around band to the projectile's body without interfering with the aerodynamic design of the projectile.

SUMMARY OF THE INVENTION

The present invention overcomes some of the disadvantages of the past including those mentioned above in that it comprises a relatively simple in design yet highly effective and efficient microstrip antenna assembly which can receive satellite provided GPS position and also transmit telemetry data. The microstrip antenna comprising the present invention is configured to wrap around the projectile's body without interfering with the aerodynamic design of the projectile.

The antenna assembly of the present invention includes a first microstrip antenna which is a telemetry antenna mounted on a dielectric substrate. The telemetry antenna transmits telemetry data to ground station or other receiving station. There is also a second microstrip antenna mounted on the dielectric substrate which is physically separated from the first microstrip antenna on the dielectric substrate. The second microstrip antenna is a GPS antenna adapted to receive satellite provided GPS position data. The antenna assembly is a wrap around antenna assembly which fits on the outer surface of a missile, target drone or any other small diameter projectile.

The telemetry antenna includes a pair of radiating elements with one radiating element being positioned on one side of the projectile and the other element being positioned on the opposite side of the projectile. One of the two radiating elements of the telemetry antenna has a feed line which provides for a 180 degree phase shift of the transmitted RF signal relative to the feed line for the other radiating element. This phase shift insures that the electric field for the transmitted RF signal is continuous around the circumference of the projectile.

The GPS antenna also has a pair of microstrip receiving antenna elements which are circularly polarized. Due to the close proximity of the telemetry and GPS antennas each antenna includes a band stop filter which are integrated into the GPS and telemetry antennas. The band stop filters have a minimum stop-band rejection of 50 decibels to prevent the telemetry data signal from saturating the GPS antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of a preferred embodiment of the present invention comprising a GPS and telemetry microstrip antenna mounted on a dielectric substrate;

FIG. **2** illustrates the isolation between the telemetry antenna and the GPS antenna of FIG. **1**;

FIG. **3** is an electrical schematic diagram illustrating an amplifier and limiter connected to the microstrip antenna of FIG. **1**;

FIG. **4** illustrates gain versus frequency for the amplifier and limiter of FIG. **3**; and

FIGS. **5** and **6** illustrate measured performance for the antenna elements of FIG. **1**;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIGS. **1**, **2**, **3** and **4**, there is shown a microstrip antenna assembly **20** comprising a telemetry antenna **22** and a GPS (Global Positioning System) antenna **24** for use on small diameter projectiles such as missiles and target drones. The diameter of the projectile **26** for which antenna assembly **20** is designed is approximately 2.75 inches.

The telemetry antenna **22** and GPS antenna **24** are separated physically and are mounted on a dielectric substrate **28**. Positioned below dielectric substrate **28** is a ground plane (not shown in FIG. **1**). Dielectric substrate **28** may be fabricated from a laminate material RT/Duroid 6002 commercially available from Rogers Corporation of Rogers Conn. This material allows sufficient strength and physical and electrical stability to satisfy environmental requirements and is also easily mounted on the surface of a missile or a target drone. The dielectric substrate **28** may be fabricated from two layers of 0.031 inch thick material, and a 0.010 inch thick antenna protective cover board. The use of the multi-layer fabrication to fabricate the substrate is to prevent wrinkling and cracking of the substrate when the dielectric **28** is mounted on the surface of the missile **130** (as depicted in FIGS. **5** and **6**).

The telemetry antenna **22** comprises two separate microstrip radiating elements/antenna transmitting elements **32** and **34** respectively fed by microstrip feed lines **36** and **38** from a single feed input point **40** as shown in FIG. **1**. The radiating elements **32** and **34** each have a shape which is rectangular and are notch fed. The element feed point **42** for radiating element **32** comprises a 100 ohm input and the element feed point **44** for radiating element **34** also comprises a 100 ohm input. The single feed input point **40** for both radiating elements **32** and **34** comprises a 50 ohm feed input. Paralleling the feed lines **36** and **38** which are 100 ohm transmission lines produces the input impedance of 50 ohms.

At this time it should be noted that the corporate feed line comprising feed lines **36** and **38** combine radiating elements **32** and **34** with equal amplitude and equal phase to maintain a match to the input 50 ohm line **40**. The corporate feed line is 100 ohms characteristic impedance so that a 50 ohm input to the line will see a 50 ohm match because the two 100 ohm lines are in parallel.

The electric field generated by the RF signal transmitted by radiating elements **32** and **34** of telemetry antenna **22** needs to be continuous around the circumference of projectile **26**. This, in turn, necessitates that one of the microstrip feed lines **36** or **38** provide for a 180 degree phase shift relative to the other feed line over the operating frequency range for telemetry antenna **22**.

The phase is matched by reversing one radiating element relative to the other radiating element to achieve a 180 degree phase difference between the two radiating elements of the telemetry antenna **22**. Phase compensation is accomplished by adding an additional one half wavelength plus an additional wavelength to antenna transmitting element **32**. The difference between the length of microstrip feed line **36** and the length of the feed line **38** adds the one half wavelength plus the additional wavelength to antenna transmitting element **32**.

There are two additional lines **45** and **47** included in the telemetry antenna **22**. Lines **45** and **47** are electrically connected to input **40** of telemetry antenna **22**. Lines **45** and **47** are open circuit transmission lines and form components of a filter **43**. Filtering is required to reduce the induced signal from the TM transmitter **22** at the GPS frequency bandwidth. Filter **43** operates as a band stop filter at the GPS frequency range which is approximately 2.25–2.29 GHz. The open circuit lines **45** and **47** are tuned so that when the lines **45** and **47** resonate at a quarter wavelength, the open circuit translates to a short circuit.

Each radiating element **32** and **34** of telemetry antenna **22** includes a pair of elongated slots **33** which are mode suppression slots.

The GPS receiving antenna **24** is also mounted on the dielectric substrate **28** in proximity to the telemetry antenna **22**. The GPS receiving antenna **24** comprises two separate microstrip antenna receiving elements **60** and **62** which respectively have feed points **64** and **66** a shown in FIG. **1**. Since antenna receiving elements **60** and **62** are required to be circularly polarized, opposed corners **69** and **71** of each element **60** and **62** are angled at approximately forty-five degrees. This results in truncated corner patches which allow for excitation of the elements **60** and **62** along their orthogonal axis. The sides **68** and **70** of each element **60** and **62** have identical lengths.

Receiving element **60** and receiving element **62** respectively have centrally located apertures **61** and **63** in their etched copper patches. The apertures **61** and **63** allow receiving elements **60** and **62** to operate effectively while reducing the size of each element **60** and **62**.

The corporate feed for GPS (Global Positioning System) antenna **24**, which comprises microstrip feed lines **74** and **76**, combine receiving elements **60** and **62** with equal amplitude and equal phase to maintain a match to the input 50 ohm line **72**. Antenna **24** includes a matching power divider identified by the reference numeral **77**. The power divider **77** includes two lines **82**A and **82**B. Lines **82**A and **82**B are open circuit transmission lines which form part of a filter **82** at the TM frequency range.

Filtering is required to reduce the induced signal from the TM transmitting antenna **22** and any other signals that are present at the TM frequency bandwidth. Open circuited line **82**A and **82**B are tuned so that when the lines **82**A and **82**B resonate at a quarter wavelength at approximately 2.25 GHz., the open circuit translates to a short circuit at power divider **77**. Filter **82** operates as a band stop filter at the TM frequency range.

Band stop filter **82** has a minimum stop-band rejection of 50 decibels. Band stop filter **78**, which is integrated into GPS antenna **24**, isolates the transmitted telemetry signal from the received GPS signal. There is a need for band stop filter **78** because of the close proximity of antenna **22** to antenna **24**.

GPS antenna **24** has the following electrical characteristics: (1) a center frequency of 1572.5 MHz which is an L-Band Radio Frequency (GPS Band L1); (2) a bandwidth of ±10 MHz (3) a circular polarization; and (4) a roll coverage of −3 db+/−5 db.

Telemetry antenna **22** has the following electrical characteristics: (1) a center frequency of 2250 MHz which is an S-Band Radio Frequency; (2) a bandwidth of ±10 MHz (3) a linear polarization; and (4) a roll coverage of −3 db+/−5 db.

Referring to FIG. **2**, there is shown a pair of plots **92** and **94**, with plot **92** being a computer simulated isolation and plot **94** being a measured isolation between the antennas **22** and **24**. Plot **90** is the required isolation of −50.00 dB. The graph **94** illustrated in FIG. **2** shows that antennas **22** and **24** meet the required isolation.

Referring now to FIGS. **1** and **3**, there is shown an electronics assembly **100** for testing the performance of an amplifier **98** and a limiter **104** electrically connected to the GPS antenna **24** of microstrip antenna **20**. The signal from GPS antenna **24** is input to assembly **100** via a threaded input connector **97**. Connecting threaded input connector **97** to limiter **104** is an etched copper line **106**. Connecting limiter **104** to amplifier **98** are a pair of etched copper lines **101** and **102**. Assembly **100** also includes an etched copper line **96** which connects amplifier **98** to a threaded output connector **95**.

Assembly **100** has a input connector **116** which allows for an electrical cable **118** to be connected to a limiter **114** via an etched copper line **115**. Assembly **100** also has an output connector **110** which is used to connect cable **108** to assembly **110**. An etched copper line **112** connects limiter **114** to connector **110**.

Amplifier **98** amplifies the signal received by GPS antenna **24**, while limiter **104** is a protective device which prevents damage to amplifier **98** when electric field has sufficient strength to damage the amplifier.

Referring to FIGS. **1**, **3** and **4**, FIG. **4** illustrates the measured response of the limiter **104** and the amplifier **102** in combination at 3 and 5 volts bias. Plot **122** is 5 volts bias, while plot **124** is 3 volts bias and plot **120** is the specified minimum gain of 26 dB at 1.575 GHz. It should be noted that the amplifier matching circuitry contributes to an additional band pass filter response to further enhance the performance of microstrip antenna assembly **20**. The measured noise was 0.9 dB at 3 volts and 1.1 dB at 5 volts.

Referring now to FIGS. **1**, **5** and **6**, the plot **138** FIG. **5**B is the measured performance of the telemetry antenna **22** in the roll plane **132** when mounted on missile **130** in the manner illustrated in FIG. **5**A. It should be noted that microstrip antenna assembly **20** includes a seam **30** as shown in FIG. **5**A. Measurements were also made in the yaw plane **134** and the pitch plane **136**. The pitch, roll and yaw responses for the telemetry antenna **22** were found to be very acceptable.

The plots **140** and **142** of FIG. **6**B are the vertical and horizontal polarization responses of the GPS (Global Positioning System) antenna **24** in the roll plane **132** when mounted on missile **130** in the manner illustrated in FIG. **5**A. Polarization measurements were also made in the yaw plane and the telemetry plane. The pitch, roll and yaw responses for the GPS antenna **24** were also very acceptable.

At this time it should be noted that the antenna elements of antenna system **20** including telemetry antenna **22** and a GPS (Global Positioning System) antenna **24** as well as band stop filters **43** and **82** are fabricated from etched copper.

From the foregoing, it is readily apparent that the present invention comprises a new, unique, and exceedingly microstrip antenna for use on a small diameter projectile, which constitutes a considerable improvement over the known prior art. Many modifications and variations of the present invention are possible in light of the above teachings. It is to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A microstrip antenna system for use on a small diameter projectile comprising:

a dielectric substrate wrapped around an outer circumference of said small diameter projectile;

a microstrip telemetry antenna mounted on said dielectric substrate, said microstrip telemetry antenna transmitting a first RF signal;

a microstrip GPS (Global Positioning System) antenna mounted on said dielectric substrate in proximity to said microstrip telemetry antenna, said microstrip GPS antenna receiving a second RF signal;

a first band stop filter integrally formed with said microstrip GPS antenna on said dielectric substrate;

a second band stop filter integrally formed with said microstrip telemetry antenna on said dielectric substrate; and

said first band stop filter and said second band stop filter providing for a minimum stop-band rejection of approximately 50 decibels to isolate the first RF signal transmitted by said microstrip telemetry antenna from the second RF signal received by said microstrip GPS antenna.

2. The microstrip antenna system of claim **1** wherein said first RF signal is an S-Band Radio Frequency signal.

3. The microstrip antenna system of claim **2** wherein said first RF signal has a linear polarization.

4. The microstrip antenna system of claim **1** wherein said second RF signal is an L-Band Radio Frequency signal.

5. The microstrip antenna system of claim **4** wherein said second RF signal has a circular polarization.

6. The microstrip antenna system of claim **1** wherein said microstrip telemetry antenna comprises:

a feed input point;

a first antenna transmitting element positioned on one side of said projectile, said first antenna transmitting element having a rectangular shape and a notch feed point;

a second antenna transmitting element positioned on an opposite side of said projectile, said second antenna transmitting element having a rectangular shape and a notch feed point;

said first antenna transmitting element and second antenna transmitting element each having a pair of elongated slots;

a first feed line having one end connected to the notch feed point of said first antenna transmitting element and an opposite end connected to said feed input point;

a second feed line having one end connected to the notch feed point of said second antenna transmitting element and an opposite end connected to said feed input point;

said first feed line and said second feed line having lengths which are sufficiently different to provide for a 180 degree phase shift of said first RF signal when transmitted by said first and second antenna transmitting elements, the 180 degree phase shift of said first RF signal insuring that an electric field for said first RF signal is continuous around the outer circumference of said projectile.

7. The microstrip antenna system of claim **6** wherein said microstrip telemetry antenna includes first and second open circuit transmission lines connected to said feed input point to form said second band stop filter.

8. The microstrip antenna system of claim **1** wherein said microstrip GPS antenna comprises:

a fifty ohm feed input;

a first antenna receiving element positioned on one side of said projectile, said first antenna receiving element having a rectangular shape which approximates a square, a centrally located aperture, and a feed point;

a second antenna receiving element positioned on an opposite side of said projectile, said second antenna receiving element having a rectangular shape which approximates a square, a centrally located aperture and a feed point;

a first feed line having one end connected to the feed point of said first antenna receiving element and an opposite end;

a second feed line having one end connected to the feed point of said second antenna receiving element and an opposite end; and

a power divider connected to said fifty ohm feed input, said power divider being connected to the opposite end of said first feed line, and the opposite end of said second feed line.

9. The microstrip antenna system of claim **8** wherein said power divider includes a pair of open circuit transmission lines to form said first band stop filter.

10. The microstrip antenna system of claim **1** wherein said microstrip telemetry antenna, said microstrip GPS antenna, said first band stop filter and said second band stop filter are fabricated from etched copper.

11. A microstrip antenna system for use on a small diameter projectile comprising:

a dielectric substrate wrapped around an outer circumference of said small diameter projectile;

a microstrip telemetry antenna mounted on a ground plane by said dielectric substrate, said microstrip telemetry antenna transmitting an S-Band Radio Frequency signal having a linear polarization;

a microstrip GPS (Global Positioning System) antenna mounted on said dielectric substrate in proximity to said microstrip telemetry antenna, said microstrip GPS antenna spaced apart from and electrically separated from said ground plane by said dielectric substrate, said microstrip GPS antenna receiving an L-Band Radio Frequency signal having a circular polarization; and

a first band stop filter integrally formed with said microstrip GPS antenna on said dielectric substrate;

a second band stop filter integrally formed with said microstrip telemetry antenna on said dielectric substrate;

said first band stop filter and second band stop filter providing for a minimum stop-band rejection of approximately 50 decibels to isolate the S-Band Radio Frequency signal transmitted by said microstrip telemetry antenna from the L-Band Radio Frequency signal received by said microstrip GPS antenna.

12. The microstrip antenna system of claim **11** wherein said microstrip telemetry antenna comprises:

a feed input point;

a first antenna transmitting element positioned on one side of said projectile, said first antenna transmitting element having a rectangular shape and a notch feed point;

a second antenna transmitting element positioned on an opposite side of said projectile, said second antenna transmitting element having a rectangular shape and a notch feed point;

said first antenna transmitting element and second antenna transmitting element each having a pair of elongated slots;

a first feed line having one end connected to the notch feed point of said first antenna transmitting element and an opposite end connected to said feed input point;

a second feed line having one end connected to the notch feed point of said second antenna transmitting element and an opposite end connected to said feed input point;

said first feed line and said second feed line having lengths which are sufficiently different to provide for a 180 degree phase shift of said S-Band RF signal when transmitted by said first and second antenna transmitting elements, the 180 degree phase shift of said S-Band RF signal insuring that an electric field for said S-Band RF signal is continuous around the outer circumference of said projectile.

13. The microstrip antenna system of claim **12** wherein said microstrip telemetry antenna includes first and second open circuit transmission lines connected to said feed input point to form said second band stop filter.

14. The microstrip antenna system of claim **11** wherein said microstrip GPS antenna comprises:

a fifty ohm feed input;

a first antenna receiving element positioned on one side of said projectile, said first antenna receiving element having a rectangular shape which approximates a square, a centrally located aperture, and a feed point;

a second antenna receiving element positioned on an opposite side of said projectile, said second antenna receiving element having a rectangular shape which approximates a square, a centrally located aperture and a feed point;

a first feed line having one end connected to the feed point of said first antenna receiving element and an opposite end;

a second feed line having one end connected to the feed point of said second antenna receiving element and an opposite end; and

a power divider connected to said fifty ohm feed input, said power divider being connected to the opposite end of said first feed line, and the opposite end of said second feed line.

15. The microstrip antenna system of claim **14** wherein said power divider includes a pair of open circuit transmission lines to form said first band stop filter.

16. The microstrip antenna system of claim **11** wherein said microstrip telemetry antenna, said microstrip GPS antenna, said first band stop filter and said second band stop filter are fabricated from etched copper.

17. A microstrip antenna system for use on a small diameter projectile comprising:

a dielectric substrate wrapped around an outer circumference of said small diameter projectile;

a microstrip telemetry antenna mounted on a ground plane by said dielectric substrate, said microstrip telemetry antenna transmitting an S-Band Radio Frequency signal having a linear polarization;

a microstrip GPS (Global Positioning System) antenna mounted on said dielectric substrate in proximity to said microstrip telemetry antenna, said microstrip GPS antenna spaced apart from and electrically separated from said ground plane by said dielectric substrate, said microstrip GPS antenna receiving an L-Band Radio Frequency signal having a circular polarization; and

a first band stop filter integrally formed with said microstrip GPS antenna on said dielectric substrate;

a second band stop filter integrally formed with said microstrip telemetry antenna on said dielectric substrate;

said first band stop filter and second band stop filter providing for a minimum stop-band rejection of approximately 50 decibels to isolate the S-Band Radio Frequency signal transmitted by said microstrip telemetry antenna from the L-Band Radio Frequency signal received by said microstrip GPS antenna;

a limiter electrically connected to said GPS antenna;

an amplifier electrically connected to said limiter, said amplifier amplifying an electrical signal provided by said GPS antenna; and

said limiter operating as a protective device to prevent damage to said amplifier.

18. The microstrip antenna system of claim **17** wherein said microstrip telemetry antenna comprises:

a feed input point;

a first antenna transmitting element positioned on one side of said projectile, said first antenna transmitting element having a rectangular shape and a notch feed point;

a second antenna transmitting element positioned on an opposite side of said projectile, said second antenna transmitting element having a rectangular shape and a notch feed point;

said first antenna transmitting element and second antenna transmitting element each having a pair of elongated slots;

a first feed line having one end connected to the notch feed point of said first antenna transmitting element and an opposite end connected to said feed input point;

a second feed line having one end connected to the notch feed point of said second antenna transmitting element and an opposite end connected to said feed input point;

said first feed line and said second feed line having lengths which are sufficiently different to provide for a 180 degree phase shift of said S-Band RF signal when transmitted by said first and second antenna transmitting elements, the 180 degree phase shift of said S-Band RF signal insuring that an electric field for said S-Band RF signal is continuous around the outer circumference of said projectile; and

said microstrip telemetry antenna including first and second open circuit transmission lines connected to said feed input point to form said second band stop filter.

19. The microstrip antenna system of claim **17** wherein said microstrip GPS antenna comprises:

a fifty ohm feed input;

a first antenna receiving element positioned on one side of said projectile, said first antenna receiving element having a rectangular shape which approximates a square, a centrally located aperture, and a feed point;

a second antenna receiving element positioned on an opposite side of said projectile, said second antenna

receiving element having a rectangular shape which approximates a square, a centrally located aperture and a feed point;

a first feed line having one end connected to the feed point of said first antenna receiving element and an opposite end;

a second feed line having one end connected to the feed point of said second antenna receiving element and an opposite end; and

a power divider connected to said fifty ohm feed input, said power divider being connected to the opposite end of said first feed line, and the opposite end of said second feed line; and

said power divider including a pair of open circuit transmission lines to form said first band stop filter.

20. The microstrip antenna system of claim **17** wherein said microstrip telemetry antenna, said microstrip GPS antenna, said first band stop filter and said second band stop filter are fabricated from etched copper.

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