United States Patent

Hallford et al.

[15] **3,638,148**

[45] **Jan. 25, 1972**

[54] LID INTERACTION PROTECTED SHIELD ENCLOSED DIELECTRIC MOUNTED MICROSTRIP

[72] Inventors: **Ben R. Hallford,** Dallas; **Carl E. Bach,** Garland, both of Tex.

[73] Assignee: **Collins Radio Company,** Dallas, Tex.

[22] Filed: **June 25, 1970**

[21] Appl. No.: **49,759**

[52] **U.S. Cl.** .....**333/84 M,** 333/12, 333/21 R, 333/33

[51] **Int. Cl.** **H01p 3/08,** H01p 5/08, H04b 15/02

[58] **Field of Search** .....333/84, 84 M, 12, 83 A, 21, 333/33, 81

[56] **References Cited**

UNITED STATES PATENTS

3,258,724	6/1966	Walsh et al.	174/35 X
2,619,539	11/1952	Fano	333/21
3,517,272	6/1970	Lee et al.	333/84 M
3,553,409	1/1971	Lehrfeld	333/84 M X

FOREIGN PATENTS OR APPLICATIONS

830,399	3/1960	Great Britain	333/84 M

OTHER PUBLICATIONS

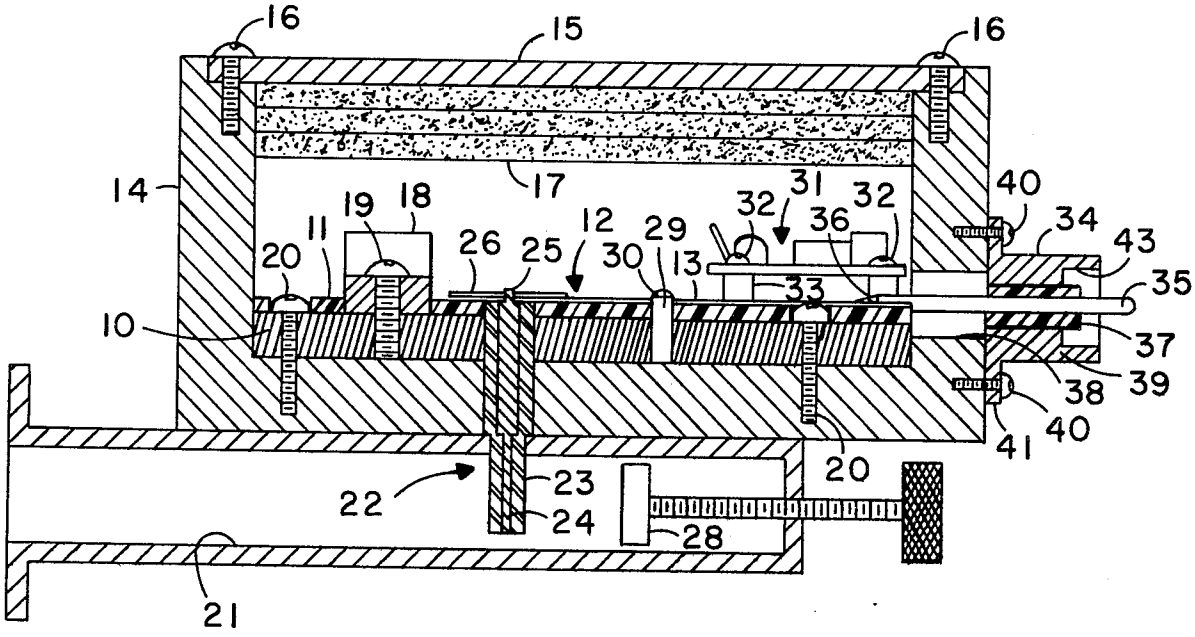
Ayer and Wheeler– The Evolution of Strip Transmission Line in the "Microwave Journal" May 1969; pp. 31, 32, 34, 36, 38, 40

Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Marvin Nussbaum
Attorney—Warren H. Kintzinger and Robert J. Crawford

[57] **ABSTRACT**

A shield enclosed microstrip circuit on a rigid relatively thick thermally and electrically conductive ground plane plate with polyolefin dielectric material approximately 0.026 inches thick having a dielectric constant within approximately the 2.3 to 2.5 range and microstrip circuitry in bonded laminate relation. RF microwave absorbent foamed material is supported within the shield enclosure in spaced generally parallel relation from the microstrip circuitry to simulate free space and eliminate "LID" effect over the microstrip circuitry.

23 Claims, 6 Drawing Figures



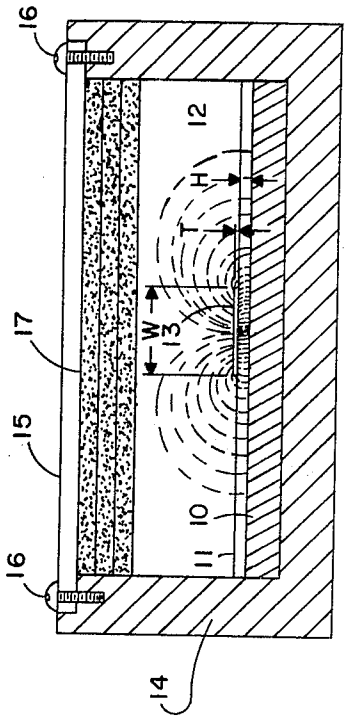


FIG. 2

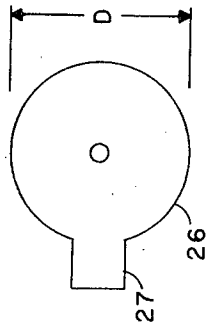


FIG. 4

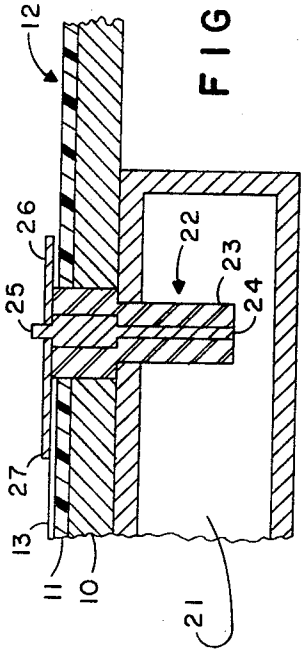


FIG. 3

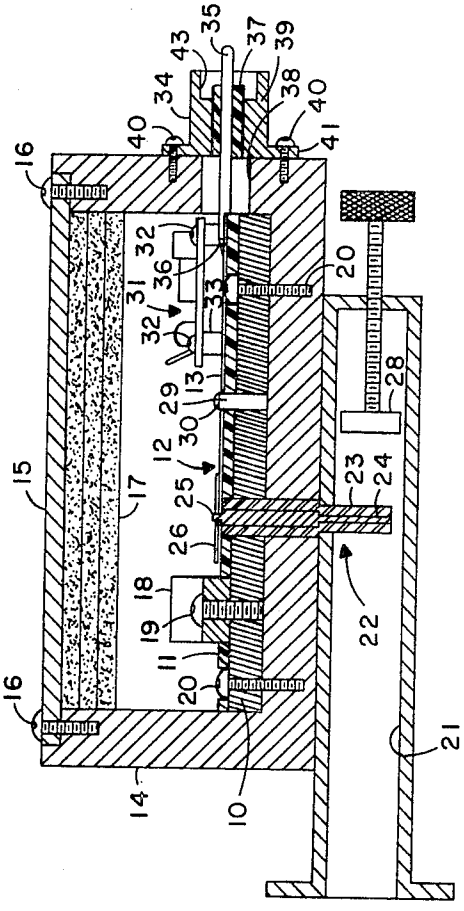


FIG. 1

INVENTORS.
BEN R. HALLFORD
CARL E. BACH
BY Warren H. Kintzinger
ATTORNEY

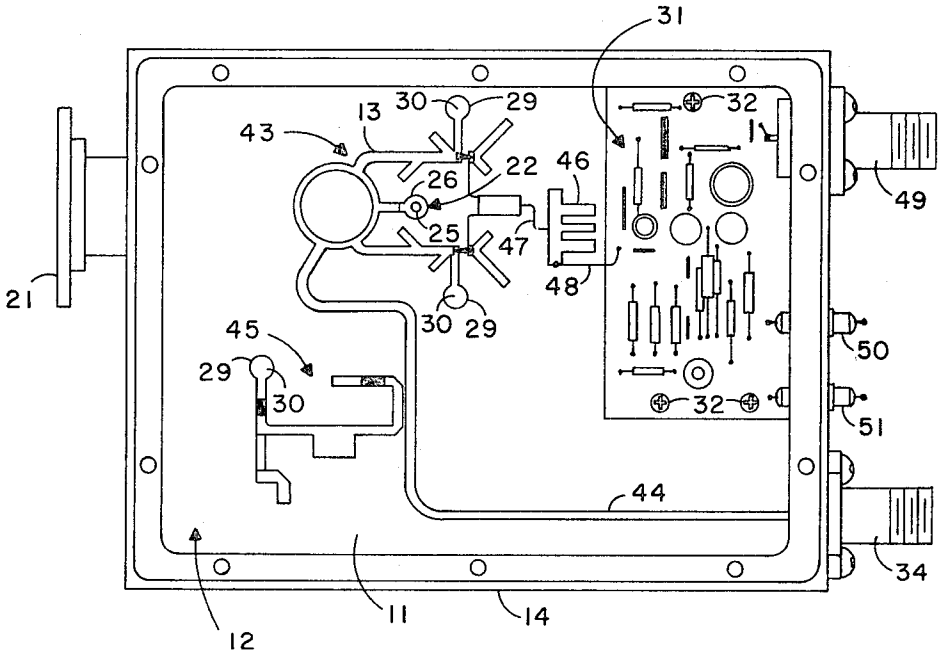


FIG. 5

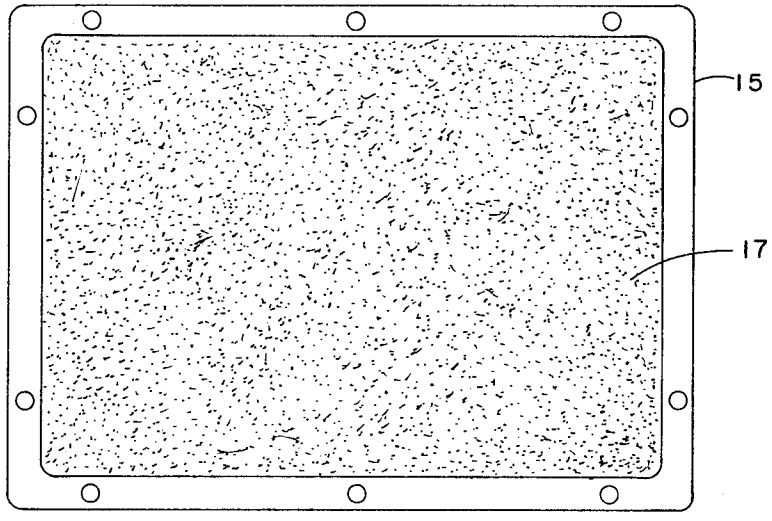


FIG. 6

INVENTORS.
BEN R. HALLFORD
CARL E. BACH
BY Warren H. Kintzinger
ATTORNEY

LID INTERACTION PROTECTED SHIELD ENCLOSED DIELECTRIC MOUNTED MICROSTRIP

This invention relates in general to microstrip circuits, and in particular, to shield enclosed plastic dielectric mounted microstrip circuits with lid interior mounted microwave energy absorbent substantially nonreflective material.

RF microwave microstrip circuits have been used to varying degrees of success through some considerable period of time in microwave communication systems in the form of etched circuits for replacing waveguide and coax structures with, for example, such techniques being popular through a period as far back as approximately 1952 when low-dielectric constant clad boards were used, but soon abandoned with the fierce radiation and interaction problems encountered. Then more recently there has been a rebirth of microstrip usage occuring about 1965 when thin film techniques were applied to form gold conductors on aluminum oxide ceramic. Use of such ceramic having a dielectric constant of approximately 9.5 causes the RF fields to be largely contained between the conductor patterns deposited on one side of the ceramic and a ground plane provided on the other side of the ceramic. The operational efficiencies attained thereby have been igniting great interest throughout the industry with resulting development attaining such great momentum as to cause a very rapid expansion of microwave integrated circuit technology. Applicants in working in this technology and building such ceramic circuits encountered such severe production quality control and fabrication requirements as to make the desirability of reevaluating other approaches and investigating alternate new approaches in overcoming manufacturing and operational problems encountered through the ceramic substrate equipped microstrip approach. While it appears that others have designed microstrip circuits on ceramic, sapphire, rutile, and other exotic higher dielectric constant materials, applicants have presented a new shielded microstrip circuit on plastic clad board approach having not only operational and manufacturing advantages, but significant cost advantages as well. It is of interest to note that many of the earlier microstrip circuits on low-dielectric constant clad boards were relatively unstable with a tendency to warp, presented mounting problems, heat sinking problems, and circuit stabilization problems. Furthermore, with shielding requirements imposed for many microstrip circuits and finished boards enclosed in a metal shielding box RF fields above copper conductors have been distorted by the metal lid with circuit performance thereby being materially altered by an amount depending upon the spacing between the lid and the microstrip circuit conductors. A considerable design effort has gone into overcoming this problem with ceramic dielectric equipped microstrip circuits and others employing such high-dielectric constant materials; however, it has remained a significant problem with even a very minute RF percentage reflection from the interior of lids parallel to the microstrip circuit conductors. This has been a problem that for all practical purposes has been substantially eliminated through the attaching of RF absorbing material to the inside of the lid of a microstrip enclosing and shielding metal box with the RF absorbing material opposite the microstrip circuit conductors.

It is, therefore, a principal object of this invention to provide a microstrip circuit on a relatively low-dielectric constant substrate that is relatively quite thin and supported by a relatively thick stiff sheet of highly conductive material acting as a ground plane for the dielectric bonded thereto and for the microstrip circuit deposited thereon.

Another object with such a microstrip circuit is to provide circuits about twice the size of those on ceramic substrates for equal circuit content, with design and maintenance advantages attained thereby along with improved ease of handling.

A further object is to provide such a microstrip circuit wherein there are enough electric field lines of force above the microstrip circuit to facilitate use of electric field interacting adjustment means.

Another object is to lower conduction loss in microstrip circuitry.

Still another object with such microstrip circuits is to materially lower manufacturing costs.

A further object is for the relatively rigid plate or sheet forming the ground plane for microstrip circuitry over a polyolefin plastic dielectric laminate on the plate to be a heat sink for heat dissipating elements used with the circuitry and mounted thereon.

Features of the invention useful in accomplishing the above objects include, in a shield enclosed microstrip circuit system, a plastic dielectric with a dielectric constant of about 2.3 having a thickness approximating 0.025 inches such as a polyolefin dielectric material with copper microcircuitry bonded to one side known as 1 ounce copper clad (0.0014 inch thick) and approximately a 0.090-inch thick aluminum plate bonded to the other side. This relatively thick metal plate, in addition to providing rigidity, also supplies a means of mounting all associated components to the assembled board and does not require precise alignment of many holes in the board to mating holes in the metal box where it is mounted. While circuits of this plastic type clad board require about twice the area that it takes for the same circuits on ceramic substrate, this size increase is actually an advantage since circuit performance is more important than size in the applications of use considered. This is with wider conductors on the plastic boards advantageously having lower conductor loss than relatively narrower conductors on ceramic substrates with conductor losses being much higher than dielectric loss of the ceramic with microstrip deposited on ceramic. This is microstrip using economical clad boards allowing the use of small semiconductor packages so that package reactance is reduced thereby allowing wide bandwidth performance to be possible. Semiconductor dice are mounted on the boards where small package reactance is excessive for the operational use intended. It lends itself to the construction by thin film techniques of capacitators and resistors suitable up to 18 GHz. operation and also to use of components constructed by thin and thick film processes on ceramic chips that may be easily bonded to conductors of the microstrip circuitry. The thickness of the substrate with a given dielectric constant is chosen so that the conductor width is a small portion of a wavelength. The 18 GHz. frequency limit stated is based on a dielectric having a thickness of 0.026 and a dielectric constant of 2.32, giving a line width of 0.077 inches for a 50-ohm line. RF field distortion above microstrip copper conductors and circuit performance interference by metal lid effect is substantially eliminated through placement of a layer of RF absorbing material approximately three-eighths inch thick on the inner side of the shield box lid with the lower face thereof approximately one-half inch from the microstrip conductors. This eliminates any need for lid effect design corrections by making the lid appear substantially as a free space impedance to the microstrip circuitry. The RF absorbing material used is a three-layer polyurethane foam with resistive compounds including carbon particles added to attain a graded bulk resistivity presenting a minimum to maximum lossetivity factor as a lossy media from the surface adjacent to the microstrip circuitry to the surface bonded to the lid inner surface.

A specific embodiment representing what is presently regarded as the best mode of carrying out the invention is illustrated in the accompanying drawings.

In the drawings:

FIG. 1 represents a side elevation cut away and sectioned view showing applicant's box shield enclosed relatively low-dielectric constant substrate bond mounted microcircuitry with lid interior mounted RF microwave energy absorbent nonreflective material;

FIG. 2, a cutaway and sectioned view of a box shielded microstrip board with a conductor illustrating parts relationship and the electric field pattern such as would be developed around a conductor;

FIG. 3, a partial cutaway and sectioned view showing RF microwave waveguide to microstrip circuit transition detail;

FIG. 4, a top view of a capacitive matching disc used at the top of waveguide to microstrip transition probe;

FIG. 5, a top plan view looking down through the top of a shield box with the lid removed showing microstrip mixer and detector circuitry and an IF preamplifier circuit mounted therein on and above the microstrip board; and

FIG. 6, a view of the lid from the bottom with RF microwave energy absorbing nonreflective material bonded thereon.

Referring to the drawings:

As shown in FIG. 1, an aluminum sheet or plate **10** backed plastic dielectric **11** equipped board **12**, with RF conductors **13** etched on a copper cladded side of the plastic dielectric laminate sheet **11**, is enclosed within RF shielding metal box **14**. The microwave circuit shielding metal box **14** is shown to be equipped with a lid **15** fastened in place on the box top as by screws **16**. The lid **15** is also shown to have a layer of RF absorbing material **17** approximately three-eighths inch thick bonded to the inner side of the shield box lid **15** so that the lower face of the RF absorbing material **17** is approximately one-half inch or more from RF conductors **13** of microstrip circuitry on board **12** within the box **14**. The microstrip board **12** is made of an aluminum metal plate **10** of approximately 0.09 inches thickness or more that not only acts as a ground plane for microstrip circuitry supported thereby, but also as a heat sink in dissipating heat energy efficiently from any high-heat energy dissipating devices that may be mounted thereon. A high-heat generating component **18** is mounted on plate **10** in an area where plastic dielectric material **11** has been removed in order that the component **18** be securely fastened down directly to the aluminum plate **10** by screws **19** and to insure a good thermal path to the plate. The board **12** with the dielectric material **11**, microstrip RF conductors **13** bonded thereto and components mounted thereon is fastened in place to the inside bottom of shield box **14** by screws **20** with dielectric removed at the screwheads in order that they may bear down directly against plate **10**, itself.

The plastic dielectric **11** used is a polyolefin plastic material approximately 0.026 inches thick that is actually irradiated polyolefin, that is, polyolefin that has been subjected to radiation process treatment to, in effect, provide a molecular alignment and stability homogeneously throughout the polyolefin plastic material. This permits the attainment of a high-dielectric homogeneity with a low-loss tangent and a plastic product having low-thickness variation with high-heat resistant as well as high-mechanical strength. This polyolefin material that has been quite advantageously employed with our microstrip box shielded circuitry is a product of Electronized Chemicals Corporation of Burlington, Massachusetts, who have been called upon to supply Collin Radio Company, the assignees of all right, title and interest to the present invention, stripline copper cladded polyolefin dielectric microstrip boards to Collins' specifications. The dielectric material height or thickness with these boards **12** is decreased to less than half the value previously used to thereby reduce the electric field in the air above the stripline conductors bonded on the upper open face of the polyolefin dielectric. Thus, a dielectric material is provided bonded on aluminum plate having a low-dielectric constant of approximately 2.3 to 2.5 with the polyolefin dielectric approximately 0.026 inches thick that has 1 ounce (0.0014 inch thick) copper bonded to the upper side for the microstrip copper conductors. Widths of microstrip conductors bonded to the low-loss isotropic dielectric **11** are so width selected as to not be an appreciable portion of a wavelength at the highest operating frequency for the circuit. Generally, knowing conductor width, material dielectric constant, and line characteristic impedance, the dielectric thickness is determined in accord with known techniques. In accord herewith for a 50 ohm line the dielectric thickness is approximately 0.025 inches when a 0.080 inch line width is chosen with 1 ounce copper clad being employed for the microstrip circuitry and with the dielectric constant being about 2.3. With this technique development of the circuit is begun by etching a pattern on the copper side to conform with calculated designs. Circuit modifications are then readily accomplished by removing copper with an exacto knife or soldering additional copper patterns at predetermined locations. A significant factor with the polyolefin dielectric equipped microstrip boards is that hermetic sealing and evacuation of air is not required such as is a must with many microwave ceramic substrate circuits since moisture does not have the adverse effect on the polyolefin material such as is inherent in the nature of ceramic substrates. It is also interesting to note that use of the lower dielectric constant material with the new circuitry presented advantageously facilitates tuning of resonant circuits with a greater portion of the electric field force lines above the circuit conductors. The presence of higher density electric fields above the conductors is turned into a useable advantage through use of slab-type adjustable position low-loss dielectrics placed over conductors to effect electrical length change and adjustable variations thereof. Further, consistent with parameters herein before set forth the polyolefin dielectric has proven to be economical, stable with temperature, chemical resistant, isotropic, and give good circuit repeatability with low losses up to 18 GHz.

Referring also to FIG. 2, the interrelationship of variable parameters are such that with decrease in any one or all three of, dielectric constant, conductor thickness, and conductor width result in increase of characteristic impedance and speed of signal propagation whereas, decrease of the height, i.e., thickness, of the dielectric material results in a decrease of characteristic impedance and a decrease in the speed of signal propagation. Further, it is a property of microstrip transmission lines to exhibit a change in its impedance and propagation velocity as a function of frequency. This effect is gradual until a critical frequency is reached where the microwave energy is no longer guided by the conductors but instead is transmitted omnidirectionally through the dielectric substrate. This phenomena has been termed a dispersion effect.

Theories have been offered to explain this effect but a universal mathematical treatment is still lacking. According to one authoritative source (C. P. Hartwig, D. Masse and R. A. Pucel, "Frequency Dependent Behavior of Microstrip," 1968 G-MTT Symposium Digest, IEEE Cat. No. 68 C 38, New York, N.Y., May 20–22, 1968, pp. 110–111) the cutoff frequency above which the conductors no longer guide the microwave energy is as follows:

$$F_c = \frac{C_0}{4h\sqrt{k-1}} \text{ in GHz.}$$

C_0 = Velocity of light in free spaces in inches/microsecond
h = Substrate thickness in inches
k = Dielectric constant of substrate

Using .026 inch thick polyolefin, the cut-off frequency would be

$$F_c = \frac{11.799079}{4(.026)\sqrt{2.32-1}}$$

$$= 98.748 \text{ GHz.}$$

From this relationship, it is obvious that a substrate may have its thickness or dielectric constant or both decreased to reduce the cutoff frequency.

Referring also to FIGS. 3 and 4 in addition to FIG. 1, a waveguide **21** to microstrip transition device **22** is provided. This includes a stepped diameter high-dielectric insulator **23** enclosing a stepped diameter conductor **24** that together project from within the waveguide **21** upward to a top probe end **25** upon which a capacity matching disc **26** is placed. This capacitive matching disc is provided with a microstrip circuit conductor overlap projection **27** and is carefully size selected for providing proper capacitive impedance match in the probe to microstrip circuitry transition from the microwave waveguide **21**. The L and S dimensions as shown in FIG. 3 are adjusted for best waveguide match using precision coax connector and termination adjustment techniques that also include adjustment of the microwave waveguide plunger **28**. Again it should be emphasized that proper choice of disc

diameter D for the capacity matching disc **26** be selected for best waveguide to microstrip match in attaining a precision microstrip termination. Another significant feature with the new microstrip circuitry is the employment of gold-plated aluminum grounding pins **29** with a conductive silver epoxy deposit **30** employed at the pin top for low-impedance ground pin **29** to circuit conductor **13** interconnect. Further, an independent subminiature board circuit such as an IF preamplifier circuit **31** may be mounted by screws **32** extended through tubular conductive metal or possibly insulation material spacers **33** for spaced support above the microstrip circuit board **12** within the shielding metal box **14** provided therefor. This circuit approach advantageously provides for the use of very short circuit leads from microstrip circuitry to an independent subcircuit such as may be necessary with high-frequency signals up to the 18 GHz. frequency range. Another feature to note is the interconnect of microstrip circuitry **13** to coax connection fixture **34** wherein the coax center conductor **35** is fitted to and soldered or brazed **36** to an end of a conductor **13**. The coax center conductor **35** is supported by dielectric material **37** in centered spaced relation to opening **38** in the wall of metal shielding box **14** with a coaxial line portion **39** of metal fixture **34** supporting the dielectric material **37** mounted in aligned relationship with the opening **38** in a wall of metal box shield housing **14** by screws **40** extended through flange **41**. The coax fixture **39** is provided with a coax line **42** receiving opening **43** for interconnect therewith in accord with conventionally known coaxial line interconnect techniques.

Referring also to FIG. **5**, a microstrip circuit board **12** application that is providing operational results is that of a shield box **14** contained microstrip circuit board including a mixer circuit **43** having a microwave waveguide **21** to microstrip transition connection via probe **22** and a capacitive matching disc member **26** that is also provided with a microstrip circuit connection **44** from a coax line interconnect through coax fixture **34** in a coaxial line connection from a local oscillator not shown that actually as one option could be contained within the box **14** itself, detail not shown. The line **44** from the local oscillator source passes by a detector circuit **45** in its circuit path to the mixer circuit **43**. Note here again that a number of the gold-plated aluminum ground pins are provided with these microstrip circuits. The mixer circuit **43** which is a balanced mixer circuit is provided with an IF signal output to RF rejection filter **46** through a high-impedance quarter wavelength (of the waveguide microwave input signal) long line **47** and the RF injection filter is provided with an IF lead connection **48** to the IF amplifier circuit **31** that is equipped with a coaxial fixture connection **49** for connection to utilizing equipment to the exterior of metal shield box **14** and the box and internal circuitry thereof is also provided with box through wall power connection fixtures **50** and **51**.

FIG. **6** shows the lid **15** of shield box **14** turned upside down with the foamed RF microwave energy absorbing nonreflective material **17** bonded thereto showing.

Whereas this invention is herein illustrated and described with respect to a specific embodiment hereof, it should be realized that various changes may be made without departing from the essential contributions to the art made by the teachings hereof.

We claim:

1. In a shield enclosed dielectric mounted microstrip circuit, a circuit board with a rigid electrically conductive ground plane plate mounting a dielectric material layer and microstrip circuitry in laminate relation thereon; said dielectric material having a relatively low-dielectric constant in the range of approximately 2 to 4 and bonded on a first side to said ground plane plate; said microstrip circuitry bonded to the second side of said dielectric material; electrically conductive shield means substantially completely enclosing the microstrip circuitry above said ground plane plate; and a materially thick layer of microwave energy absorbent substantially nonreflective material supported within said electrically conductive shield means in, generally, overlying spaced relation to the said microstrip circuitry.

2. The shield enclosed dielectric mounted microstrip circuit of claim **1**, including at least one signal path structure extending from the exterior of said electrically conductive shield means to connection with said microstrip circuitry; and with said signal path structure having a coaxial center conductor supported by dielectric from outer conductive means.

3. The shield enclosed dielectric mounted microstrip circuit of claim **2**, wherein said signal path structure is a coaxial line fixture for connection with an external coaxial transmission line.

4. The shield enclosed dielectric mounted microstrip circuit of claim **2**, wherein said signal path structure is a microwave probe with the coaxial center conductor extended into a waveguide external to said electrically conductive shield means with the probe structure a microwave waveguide to microstrip circuit transition device.

5. The shield enclosed dielectric mounted microstrip circuit of claim **4**, wherein a capacity matching disc is mounted on the probe to microstrip circuit interconnect end of said microwave probe structure.

6. The shield enclosed dielectric mounted microstrip circuit of claim **1**, wherein said dielectric material layer is a layer of polyolefin.

7. The shield enclosed dielectric mounted microstrip circuit of claim **6**, wherein signal transmission lines of said microstrip circuitry are relatively narrow relative to the shortest RF signal wavelength transmitted through said signal transmission lines.

8. The shield enclosed dielectric mounted microstrip circuit of claim **7**, wherein said microstrip circuitry transmission lines and dielectric material thickness are sized for line characteristic impedance to be a design selected value from within the range of from approximately 10 ohms to 150 ohms.

9. The shield enclosed dielectric mounted microstrip circuit of claim **7**, wherein the microstrip circuitry is dimensioned for microwave RF frequencies up to approximately 18 GHz.

10. The shield enclosed dielectric mounted microstrip circuit of claim **9**, wherein said polyolefin dielectric material layer is approximately 0.026 inches thick.

11. The shield enclosed dielectric mounted microstrip circuit of claim **10**, wherein said microstrip circuitry transmission lines are approximately 0.077 inches wide and approximately 0.0014 inches thick.

12. The shield enclosed dielectric mounted microstrip circuit of claim **11**, wherein said microstrip circuitry transmission lines are 50 ohm lines.

13. The shield enclosed dielectric mounted microstrip circuit of claim **6**, wherein said polyolefin is irradiated polyolefin.

14. The shield enclosed dielectric mounted microstrip circuit of claim **6**, wherein additional circuit means is mounted within said shield enclosure means.

15. The shield enclosed dielectric mounted microstrip circuit of claim **14**, wherein a circuit board carries said additional circuit means.

16. The shield enclosed dielectric mounted microstrip circuit of claim **15**, wherein said circuit board includes an IF amplifier circuit; said microstrip circuitry includes a mixer circuit; and a relatively short jumper lead from said microstrip circuitry to said IF amplifier circuit.

17. The shield enclosed dielectric mounted microstrip circuit of claim **1**, wherein said ground plane plate mounts heat generating component means, with said heat generating component means mounted in direct contact with said ground plane plate in an area where said dielectric material layer is removed; and with said ground plane plate a heat sink for said heat generating component means.

18. The shield enclosed dielectric mounted microstrip circuit of claim **17**, wherein said ground plane plate is a sheet of aluminum with at least the rigidity of an aluminum sheet approximately 0.090 inches thick.

19. The shield enclosed dielectric mounted microstrip circuit of claim **1**, wherein said layer of microwave energy absorbent substantially nonreflective material has a graded bulk resistivity presenting a minimum to maximum lossetivity factor

as a lossy media from the layer surface closest to the microstrip circuitry to the surface bonded to support means within said electrically conductive shield.

20. The shield enclosed dielectric mounted microstrip circuit of claim **19**, wherein said layer of microwave energy absorbent substantially nonreflective material is spaced at least three-eighths of an inch from said microstrip circuitry.

21. The shield enclosed dielectric mounted microstrip circuit of claim **20**, wherein said layer of microwave energy absorbent substantially nonreflective material is at least one-fourth inch thick.

22. The shield enclosed dielectric mounted microstrip circuit of claim **21**, wherein said layer of microwave energy absorbent substantially nonreflective material is a plurality of layers bonded together.

23. The shield enclosed dielectric mounted microstrip circuit of claim **18**, wherein gold-plated aluminum ground pins are used at ground points of said microstrip circuitry pressed into drilled openings through the dielectric material laminate and ground plane plate; and with a conductive material to microstrip interconnect deposit on the ground pin microstrip ends.

* * * * *