Feb. 4, 1964 E. F. BUCKLEY 3,120,641

MICROWAVE ANECHOIC CHAMBER

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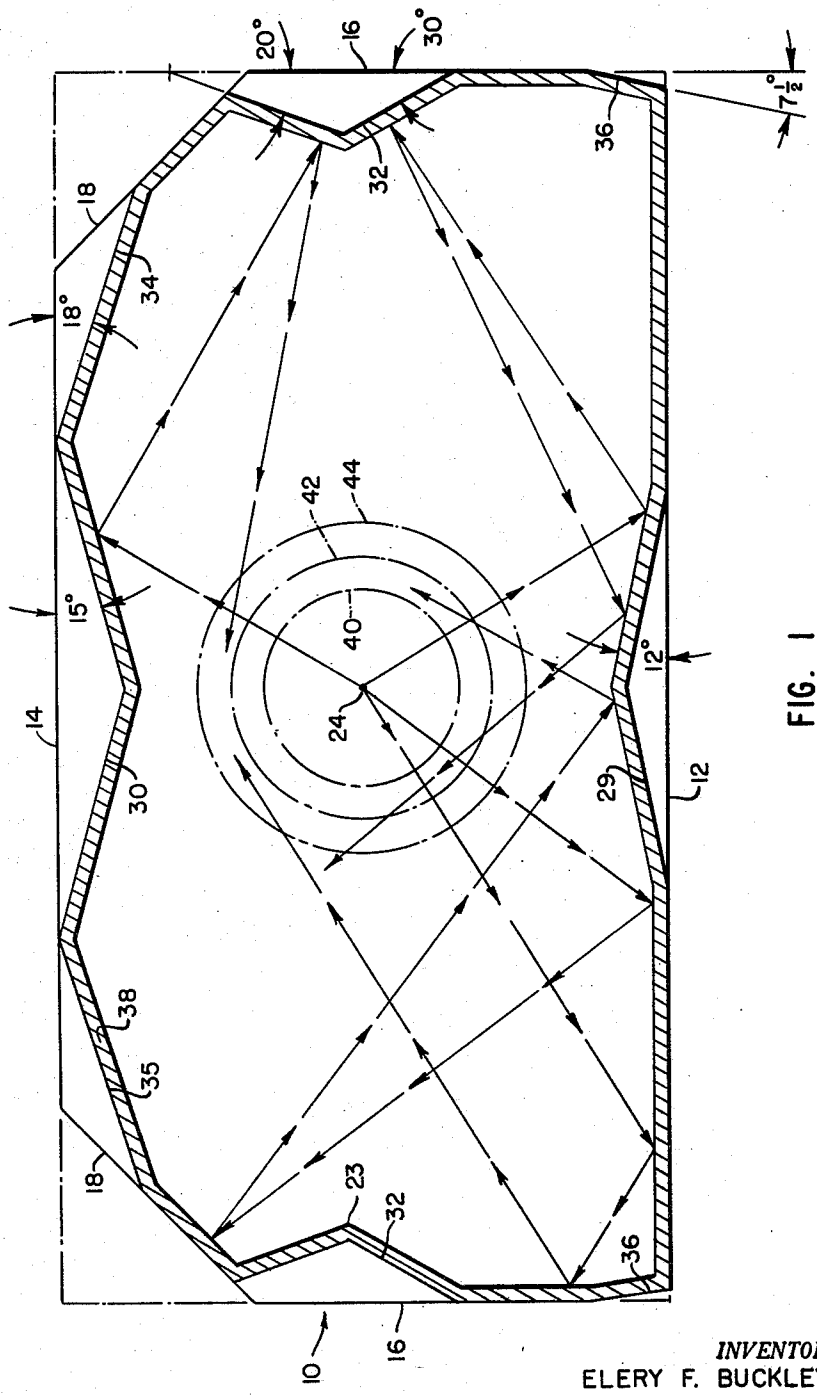


FIG. 1

INVENTOR.
ELERY F. BUCKLEY

BY KENWAY, JENNEY, WITTER & HILDRETH

ATTORNEYS

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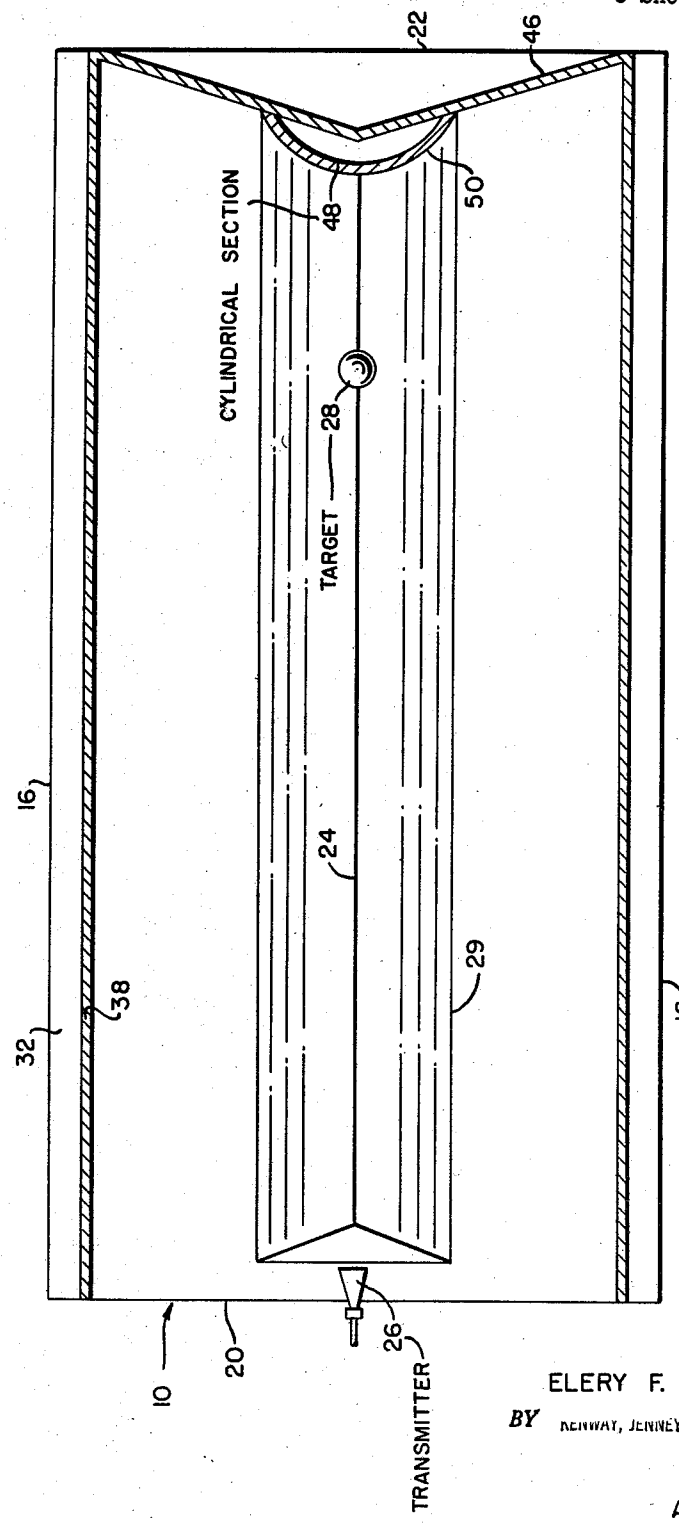


FIG. 2

INVENTOR.
ELERY F. BUCKLEY
BY KENWAY, JENNEY, WITTER & HILDRETH
ATTORNEY

Feb. 4, 1964 E. F. BUCKLEY 3,120,641

MICROWAVE ANECHOIC CHAMBER

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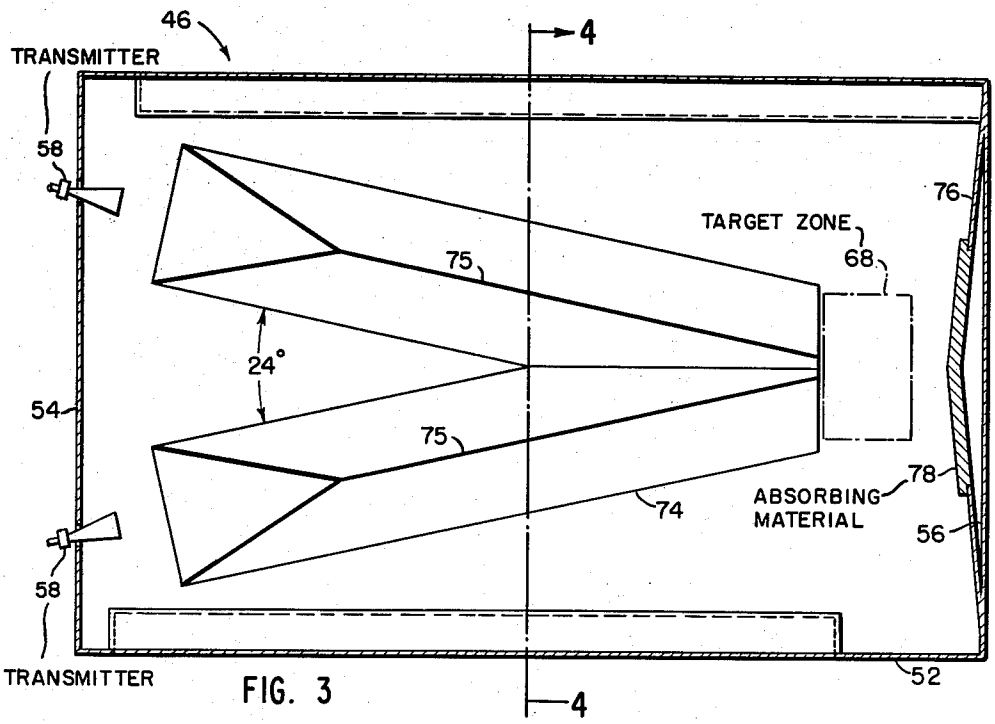
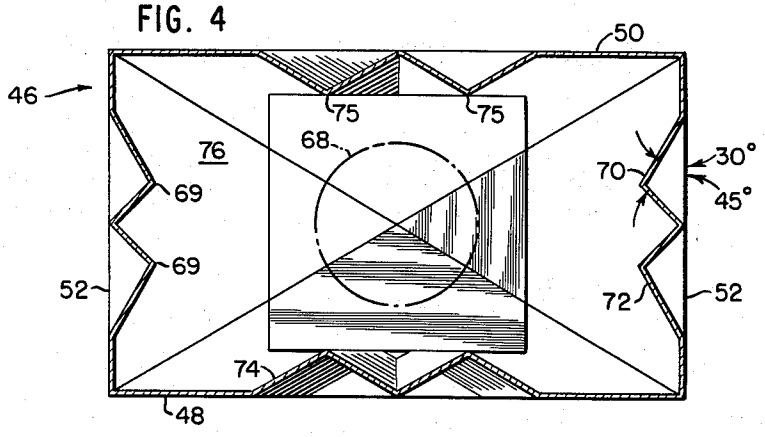


FIG. 3

FIG. 4



INVENTOR.
ELERY F. BUCKLEY
BY KENWAY, JENNEY, WITTER & HILDRETH

ATTORNEYS

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MICROWAVE ANECHOIC CHAMBER

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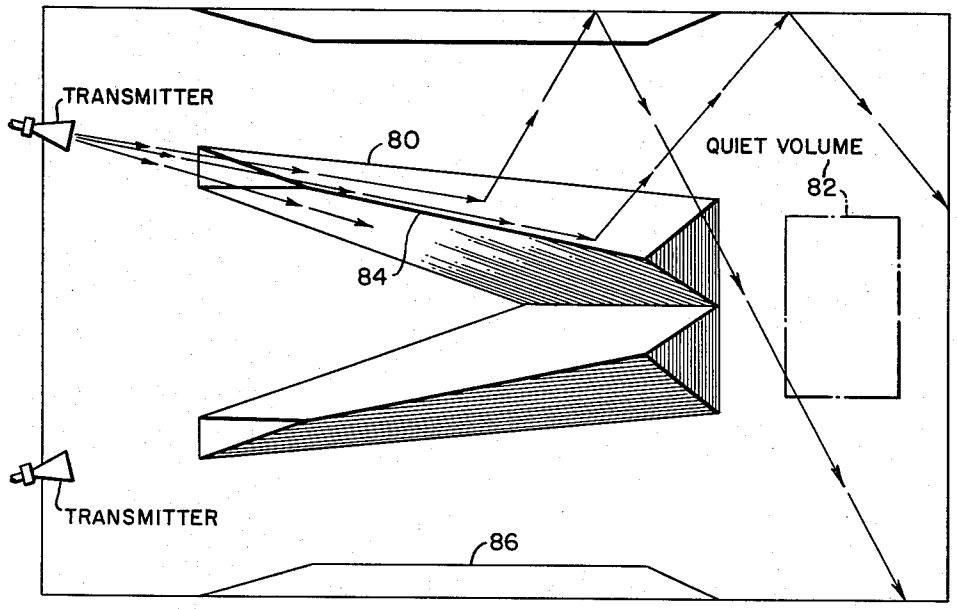
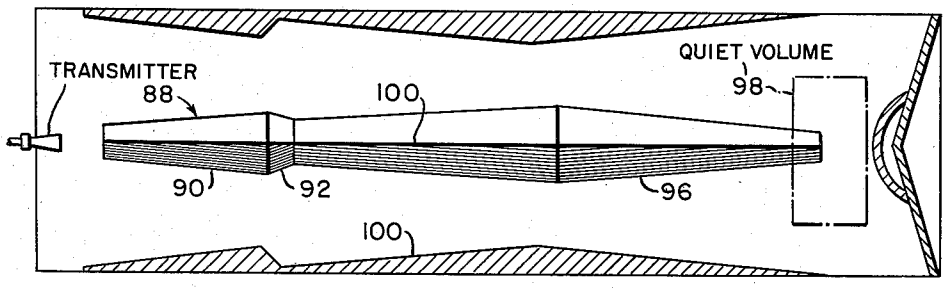


FIG. 5

FIG. 6



INVENTOR.
ELERY F. BUCKLEY
BY
KENWAY, JENNEY, WITTER & HILDRETH
ATTORNEYS

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FIG. 7

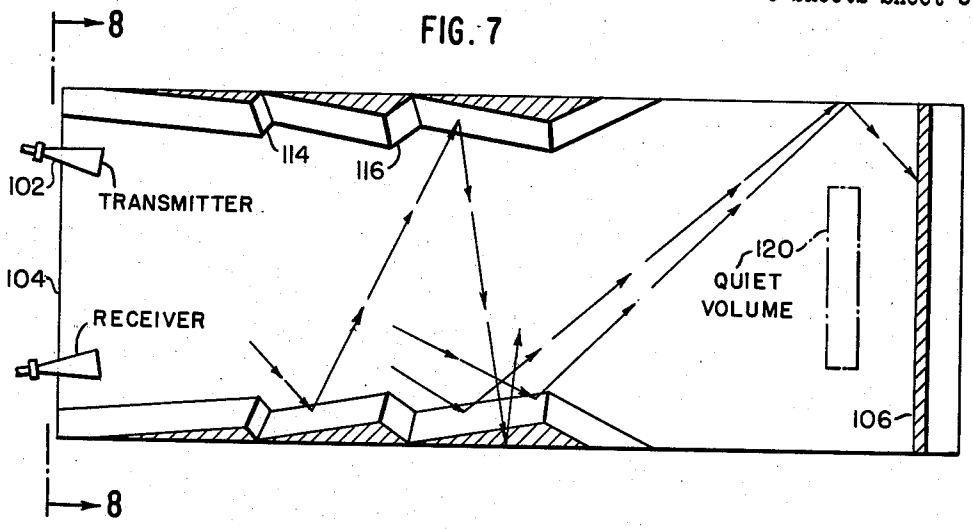
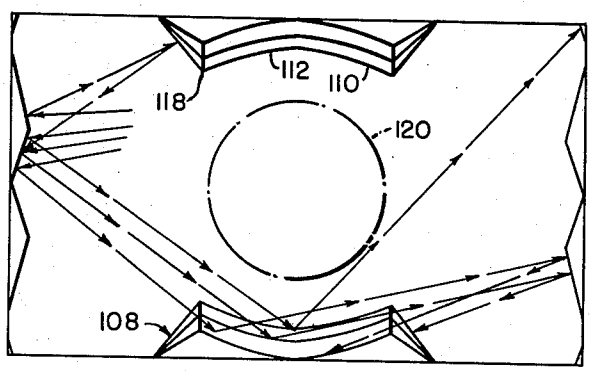


FIG. 8



INVENTOR.
ELERY F. BUCKLEY

BY KENWAY, JENNEY, WITTER & HILDRETH

ATTORNEYS

United States Patent Office

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MICROWAVE ANECHOIC CHAMBER

Elery F. Buckley, Concord, Mass., assignor to Emerson & Cuming, Inc., Canton, Mass., a corporation of Massachusetts

Filed June 8, 1960, Ser. No. 34,751
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This invention relates in general to microwave darkrooms and more particularly to a new and improved microwave anechoic chamber in which a plurality of reentrant baffles are mounted on the floor, ceiling and side walls of the chamber with their crest lines arranged generally lengthwise with respect to the room Extraneous energy, generated by a transmitter located within the chamber and normally aimed along the length thereof, will be reflected about the chamber and away from a quiet volume of limited dimensions wherein a test object is normally located.

Many radio-wave anechoic chambers have been constructed as simple rectangular boxes lined with absorber materials, which reduce reflectivity of electromagnetic energy from walls, ceilings and floors within the functional frequency range of the absorbers used. Absorbing materials are now available which reflect less than one percent of the electromagnetic energy within the frequency range of 50 mc. to 50 kmc. These one percent materials are normally referred to as 20 decibel or 20 db absorbers. A few materials are available which exhibit power reflectivity of 30 db (0.1%) and even 40 db (0.01%) over limited portions of this frequency range.

While it would be possible to line the entire test chamber with material of high absorption characteristics, it would not be practical from an economical standpoint. Absorbing materials in the 30–50 db range, at present, are costly and considerably more expensive than the 20 db absorbers. Furthermore, the performance of a box-like room lined with a 20 db absorber, for instance, has seldom been better than 25–30 db because of essentially specular single-bounce reflections from the flat walls, ceiling and floor at points approximately midway between the transmitter and the receiver.

In some instances, absorber-covered baffles project into the test chamber from the walls, ceiling and floor so that the baffle edges, or crests, lie in planes normal to the line of sight between the transmitter and the target. While the baffles are intended to re-direct specularly reflected energy away from some quiet volume of limited dimensions wherein the test object must be located, the design of such transverse baffles is extremely difficult if a large quiet volume is required, or if a range of distance between the quiet volume and the transmitter is necessary. Moreover, the diffraction effects from baffle edges, which are normal to the line of sight between the transmitter and the target, present an inherent limitation on room performance.

It is an object of the present invention to provide a microwave anechoic chamber wherein there exists a quiet volume extending essentially the entire length of the room and about the line of sight between the transmitter and the test object.

Another object of this invention is to provide a microwave anechoic chamber in which there is no limitation imposed by the reflectivity characteristics of the room itself upon the distance between the transmitter and the target within the room.

Yet another object of this invention is to improve room anechoic performance of microwave anechoic chambers without resort to highly absorptive materials.

Still another object of this invention is to provide a microwave anechoic chamber whose decibel performance

is significantly greater than the decibel reflectivity of the absorbing material used to cover the major portions of the walls, ceiling and floor.

A major feature of the invention is a microwave anechoic chamber in which a plurality of absorber-covered reentrant baffles are provided on the floor, walls and ceiling with the baffle edges or crests disposed generally lengthwise with respect to the room and approximately parallel to the direction of propagation. The baffles are so oriented and designed that electromagnetic energy originating from a transmitter located at one end of the room will be reflected specularly about the walls, ceiling and floor without passing through a "free-space" zone of limited dimensions which may extend approximately the entire length of the room. The free-space zone, or quiet volume as it is more commonly known, has dimensions subject to design control and surrounds the line of sight between the transmitter and the test object. The test target, such as absorbers, reflectors, antennas and the like, may be located at any position in this zone without interference from reflected electromagnetic energy.

These and other novel features of the invention together with further objects and advantages thereof will become apparent from a reading of the following detailed specification with reference to the accompanying drawings in which:

FIG. 1 is a cross-sectional view in elevation of a radio-frequency anechoic chamber made according to my invention,

FIG. 2 is a plan section of a chamber shown in FIG. 1,

FIG. 3 is a plan section of a modification of my invention,

FIG. 4 is a cross-sectional view taken along the line 4—4 of FIG. 3,

FIG. 5 is a plan view showing a modification of the FIGS. 3 and 4 embodiment,

FIG. 6 is a plan view showing a modification of the FIGS. 1 and 2 embodiment,

FIG. 7 is a sectional view in side elevation showing further modifications of the invention, and

FIG. 8 is a cross-sectional view taken along the line 8—8 of FIG. 7.

Referring now to the drawings, the reference character 10 of FIGS. 1 and 2 generally indicates an elongated chamber of nearly rectangular cross section having a floor 12, a ceiling 14, opposed side walls 16 and diagonal portions 18 between the side walls and the ceiling. A pair of oppositely facing end walls 20 and 22 complete the frame work of the chamber. The structural material used in the chamber is not critical, the only requirements being that the chamber be reasonably sturdy and capable of excluding the elements. The interior of the chamber 10 is lined by a plurality of re-entrant baffles having their edges or crest lines 23 disposed generally lengthwise of the room and parallel to a longitudinal center line or axis 24.

Typical dimensions of the chamber shown in FIGS. 1 and 2 would include an overall length of 110 feet, a height of 20 feet and a width of 40 feet. These dimensions are only by way of example and may be varied according to the particular needs and available space.

In practice, when testing radio-wave devices, a transmitter 26 and a target 28 are mounted roughly at opposite ends of the chamber as shown in FIG. 2. The transmitter should normally be mounted in line with the room axis and aimed at the target which also should normally be located along this axis. The distances separating the target and the transmitter may be varied as desired as long as both remain on or near the axis. In taking reflectivity measurements the reflector will normally be centered along the axis while the transmitter and detec-

tor will be spaced slightly apart from one another on or near the end wall 20.

The longitudinal re-entrant baffles include a floor baffle 29, defining an isosceles triangle in cross-section with base angles of 12°. A ceiling baffle 30 is also an isosceles triangle in cross-section but is somewhat wider than the floor baffle 29 and has base angles of 15°. Each side wall 16 is provided with identically shaped re-entrant baffles 32, triangular in cross-section, with the upper face inclined 20° from the wall and the lower face inclined 30°, as indicated. It will be understood that the arrangement is substantially symmetrical, i.e. lines connecting the apices of the side wall baffles 32 would intersect the lines connecting the apices of the ceiling and floor baffles 30 and 29 roughly at the room axis 24 along which the test equipment is located.

Supplementary baffles 34, inclined 18° down from the horizontal, extend from the base of the ceiling baffle 30 to a point near the center of the diagonal member 18. Additional supplementary baffles 36 are provided at each of the lower corners of the room and are set at 7½° from the vertical.

These baffles, as well as the flat portions of the floor, walls and ceiling, have their inner surfaces covered with microwave absorbing material 38 which may have a nominal reflectivity of 20 db. The formation of the baffles is such that electromagnetic energy impinging upon them from a transmitting point, which is shown located along the room axis but which can provide satisfactory performance when located off the room axis, is generally reflected away from the chamber axis. This axis has been described as generally coinciding with the line of sight between the transmitter and the test target.

In the embodiment of FIG. 1, no reflected electromagnetic energy passes through a 6 foot diameter cylinder 40, located about the axis 24, until it has undergone at least three reflections from the absorbing material 38. Only a very few second-bounce reflections pass through a concentric 8 foot diameter cylinder 42 and no first-bounce reflections pass through a concentric 10 foot diameter cylinder 44. Typical ray paths generated from a transmitter located along the axis 24 and appearing as directional lines in FIG. 1, clearly illustrate the function of the longitudinal re-entrant baffles.

Two immediate advantages are derived from the placement of the re-entrant baffles lengthwise with their crests generally parallel to the axis of propagation. First, baffle edge diffraction effects are minimized since the edges or crests are parallel to the axial field components which are relatively small in most instances. Secondly, the residual and unavoidable reflections from longitudinal baffles impose no limitation on the distance between the transmitter and the target. A uniformly quiet volume having dimensions subject to design control surrounds the longitudinal axis of the chamber and extends to within a few feet of either end.

The end wall 22 of the chamber is provided with a shallow vertical wedge 46 pointing into the room, but the sharp forward edge is shielded by a section 48 of a vertical cylinder covered with absorbing material 50 of 30–40 db nominal reflectivity. The end wall 20 may be covered with absorbing material if desired or may be constructed in the same manner as the end wall 22 for transmitting in either direction.

The absorbing material 38 used in this chamber is functional from about 900 mc. to upwards of 50 kmc. For reflectivity work at X-band (approximately 10 kmc.), tests have shown that under typical illumination conditions and a target distance of at least 25 feet, the energy reflected from the room is 35 to 40 db below the energy reflected from a 12 inch diameter flat metallic reference plate. A similar performance figure applies for pattern recording work at L-band (approximately 1.2 kmc.) at 50 feet and at X-band at 85 feet under similar conditions. The room performance is therefore 15–20 db better than 20 db nominal reflectivity of the absorbing material 38 which covers most of the interior surfaces.

By way of explanation, the term room performance is used to define, in a general manner, the darkness or quietness of a microwave darkroom. When applied to the use of an anechoic chamber for antenna pattern measurement, room performance may be defined as the ratio between the direct power density and reflected power density at the site of the test antenna under specific conditions of chamber illumination. When applied to the use of an anechoic chamber for reflectivity measurements, the term refers to the ratio between the maximum power returned to the detecting system by some standard reflector and that returned by the room itself in the absence of the standard reflector, again under specific conditions of room illumination.

FIGS. 3 and 4 show a modification of the invention suitable for the illumination of a single target area at one end of the chamber from four transmitting ports, located in an opposite end wall. For taking reflectivity measurements, one or more of these ports may be used to accommodate receiving equipment.

In this embodiment, an elongated chamber 46 of rectangular cross-section is provided with a floor 48, a ceiling 50, side walls 52 and end walls 54 and 56. Four transmitters 58 are mounted approximately symmetrically on the end wall 54 and focused on a target zone 68 located near the end wall 56. Having a rated performance level of 40 db, the target zone is about 10 feet in diameter and 6 feet long and is centered on the longitudinal axis of the room. The room itself is about 36½ feet wide, 56 feet 8 inches long and 21 feet 5 inches in height. The side walls 52 are provided with longitudinally disposed re-entrant baffles of triangular cross-section extending approximately the entire length of the room with their crest lines 69 parallel to the floor and ceiling. An upper side wall baffle 70 has its upper face inclined at a 30° angle out from the wall while its lower face is inclined at a 45° angle. A lower side wall baffle 72 has a similar configuration but in reversed position so that its upper face is inclined at 45° while the lower face is at 30°. Both baffles extend about 2½ feet into the room and cover about 13 feet 7 inches of the height of the side walls.

Longitudinal re-entrant baffles 74 are provided on the floor and ceiling with their crest lines 75 running approximately parallel to the vertical planes containing the lines of sight from the transmitters to the target area 68. As clearly shown in FIG. 3, the baffles 74 converge at an angle of 24° toward the quiet volume. Ray tracing in this chamber showed that no second-reflection rays entered the quiet volume 68.

The end wall 56 adjacent to the quiet volume, has a shallow four-sided pyramid 76 whose tip is covered with a 40 db absorbing material 78. The remaining inner surfaces of the room, including the baffles, are covered with an absorbing material of 20 db reflectivity. Despite the fact that the major portions of the chamber surfaces are covered with a 20 db absorbing material, the quiet volume has a performance rated at 40 db, indicating a 20 db improvement over the material used.

It will be obvious that the size as well as the shape of the quiet volume may be altered by varying the number, the position as well as the angularities of the baffle faces. A quiet volume involving a rather large proportion of the entire chamber may be achieved by longitudinal re-entrant baffles that protrude into the room to a considerable extent. By proper design of the baffles, the quiet volume may take the form of a square tube centered about the longitudinal axis of the room. While the invention has been described with reference to elongated generally rectanglar chambers, it may be used to equal advantage in cubical structures as well as in rooms of non-standard or asymmetrical configurataion with proper consideration given to the shape and placement of the baffles.

In FIG. 5, there is illustrated a modification of the FIG. 4 embodiment. In this instance, the chamber is provided with converging floor and ceiling baffles 80 which gradually widen and increase in height as they appoach the quiet volume. The purpose of tapering the baffles in this manner is to direct residual crest line reflections away from the quiet volume 82. It will be appreciated from a study of the ray traces of FIG. 5 that electromagnetic energy impinging on or near the baffle crest line 84 will be reflected about the room to pass either in front of or behind the quiet volume 82.

While the chamber shown in FIG. 5 is provided with re-entrant side wall baffles 86 having beveled end portions and a crest line parallel to the room axis, it will be understood that these baffles may also be formed with a tapered configuration similar to the floor and ceiling baffles described. It will also be understood that the inner surface of the chamber may be covered with absorbing material such as that described in connection with the FIG. 3 chamber.

In FIG. 6, there is illustrated an anechoic chamber characterized by longitudinal re-entrant baffles 88 mounted on the walls, ceiling and floor. In this embodiment, the baffles are formed with multiple tapers commencing with a rather short section 90 tapering outwardly and upwardly and merging with a short inwardly tapered section 92. This, in turn, joins a rather long outwardly tapered section 94 and inwardly tapered section 96 of similar length. As in the case of the FIG. 4 structure, the tapering of the baffles serves to set the crest lines 100 at an angle with respect to the line of sight between the transmitter and the target. Residual crest line reflections will thus be directed away from a quiet volume 98 which, in this case, will be somewhat shorter than the FIG. 1 arrangement and located near the receiving end of the chamber.

A similar effect can be achieved by fabricating the baffle 88 in such a manner that the base lines of the baffle remain parallel while the angles of the baffle side surfaces are altered in a certain region or regions along their length. The crest lines of such a baffle will protrude by a greater or lesser distance into the chamber with appropriate transition regions between the different sections. As before, absorbing material may line the interior of the chamber.

Referring now to FIGS. 7 and 8, there is shown an anechoic chamber which in some respects is a modification of the chamber illustrated in FIG. 3. The chamber of this embodiment is suitable for housing a number of transmitters or receivers, 102 located in spaced array on an end wall 104 and aimed in the direction of an opposite end wall 106. The walls, ceiling and floor are provided with longitudinal re-entrant baffles extending generally lengthwise with respect to the room. In this instance, however, the floor and ceiling baffles 108 are in the form of parallel crest portions 110 joined by an arcuate longitudinal trough 112. The baffle is stepped as at 114 and 116 so that the crest lines 118 taper alternately towards and away from the axis of propagation. In this fashion, energy striking the crest will not be reflected into the quiet volume 120 until it has suffered at least three reflections as indicated by the ray traces of FIGS. 7 and 8.

While the invention has been described with particular reference to the illustrated embodiments, it will be obvious that many modifications will appear to those skilled in the art without departing from the spirit of the invention. For instance, the crest lines of the baffles may curve to and away from the axis of propagation rather than being formed with the linear tapers illustrated in connection with FIGS. 5–8.

Having thus described my invention, what I claim and desire to obtain by Letters Patent of the United States is:

1. A microwave anechoic chamber for housing means for propagating microwaves in one general direction and a target, comprising supporting means defining an enclosure, a plurality of re-entrant baffles mounted on said supporting means, said baffles being large with respect to the wavelength of said microwaves and having crest lines oriented generally parallel with respect to the direction of propagation of said microwaves whereby extraneous microwaves are directed away from a quiet volume of limited dimensions within which said target is normally located.

2. A microwave anechoic chamber for housing means for propagating microwaves in one general direction, comprising supporting means defining an enclosure, a plurality of re-entrant baffles mounted on said supporting means, microwave absorbing material of relatively low decibel performance covering said baffles, said baffles being large with respect to the wavelength of said microwaves and having crest lines oriented generally parallel with respect to the direction of propagation of said microwaves whereby extraneous microwaves are directed away from a quiet volume of relatively high decibel performance.

3. A microwave anechoic chamber for housing means for propagating microwaves in one general direction and a target, comprising supporting means defining an enclosure, a plurality of re-entrant baffles mounted on said supporting means, microwave absorbing material of approximately 20 db reflectivity covering said baffles, said baffles being large with respect to the wavelength of said microwaves and having crest lines oriented generally parallel with respect to the direction of propagation of said microwaves whereby extraneous microwaves are directed away from the line of sight between said transmitters and said target to define a quiet volume of approximately 35 to 40 db.

4. A microwave anechoic chamber for housing means for propagating microwaves in one general direction, comprising a plurality of walls assembled to define an enclosure, elongated re-entrant baffles formed on the inner surfaces of said walls, microwave absorbing material of relatively low decibel performance covering said walls and said baffles, said baffles being large with respect to the wavelength of said microwaves and having crest lines disposed generally lengthwise with respect to the direction of propagation of said microwaves whereby extraneous microwaves are directed away from a quiet volume of relatively high decibel performance.

5. A microwave anechoic chamber for enclosing a microwave transmitter and target mounted in spaced relation to one another, including a floor, ceiling and opposing side walls connected to define a housing and arranged generally lengthwise with respect to the line of sight between said transmitter and said target, end walls enclosing said housing, and a plurality of elongated re-entrant baffles provided on said floor, ceiling and side walls and disposed generally lengthwise with respect to said line of sight, said baffles being formed with a lengthwise taper to reflect extraneous energy about said housing to define a quiet volume of limited dimension about the line of sight between said transmitter and said target.

6. A microwave anechoic chamber for housing a microwave transmitter and target in spaced relation to one another, comprising a plurality of walls assembled to define an enclosure, a plurality of re-entrant baffles disposed on said walls and arranged generally lengthwise with respect to the line of sight between said transmitter and said target, each of said baffles being large with respect to the wavelength of said microwaves and being formed with crest lines tapering toward and away from said line of sight to reflect extraneous energy about said walls to define a quiet volume of limited dimensions about said line of sight.

7. A microwave anechoic chamber for housing a microwave transmitter and target in spaced relation to one another, comprising a plurality of walls assembled to define an elongated enclosure, a plurality of re-entrant baffles

disposed on said walls and arranged generally lengthwise with respect to said enclosure, each of said baffles being large with respect to the wavelength of said microwaves and being formed with a pair of parallel crest portions formed lengthwise of said baffles and defining a trough therebetween, each of said baffles also being formed with portions tapering alternately towards and away from the line of sight between said target and transmitter.

8. A microwave anechoic structure for enclosing a microwave transmitter and target mounted in spaced relation to one another, including a floor, ceiling and opposing side walls connected to define a housing and arranged generally lengthwise with respect to the line of sight between said transmitter and said target, end walls enclosing said housing, and a plurality of radio-wave reflecting re-entrant baffles provided on said floor, ceiling and side walls, said baffles being formed with crest lines oriented generally lengthwise of said room and adapted to reflect extraneous energy about said housing to define a quiet volume of limited dimensions about the line of sight between said transmitter and said target.

9. A microwave anechoic structure according to claim 8 in which the end wall opposite said transmitter is provided with an inwardly projecting shallow wedge, said wedge being vertically disposed.

10. A microwave anechoic structure according to claim 9 in which the crest of said wedge is shielded by a section of a vertically disposed cylinder.

11. A microwave anechoic structure for enclosing a target and a plurality of microwave transmitters spaced from and focused on said target, including a floor, ceiling and opposing side walls connected to define a housing and arranged generally lengthwise with respect to the lines of sight between said transmitters and said target, end walls enclosing said housing, a plurality of radio-wave reflecting re-entrant baffles provided on said floor, ceiling and side walls, at least the baffles on said floor and ceiling being formed with crest lines running parallel to said lines of sight, said baffles being oriented to reflect extraneous electromagnetic energy about said housing to define a quiet volume of limited dimensions about said lines of sight.

12. A microwave anechoic structure according to claim 11 wherein the end wall opposite said transmitter is formed as a shallow pyramid projecting into said housing.

13. A microwave anechoic chamber according to claim 11, wherein at least one of said end walls is provided with an inwardly projecting protrusion to reflect electromagnetic energy away from said quiet volume.

14. A microwave anechoic structure for housing means for propagating microwaves in one general direction and means for reflecting said microwaves in a generally opposite direction, comprising a plurality of walls assembled to define an enclosure, elongated re-entrant baffles formed on the inner surfaces of said walls, microwave absorbing material of relatively low decibel performance covering said walls and said baffles, said baffles being large with respect to the wavelength of said microwaves and having crest lines disposed generally lengthwise with respect to the direction of propagation and reflection whereby extraneous microwaves are directed away from a quiet volume of relatively high decibel performance.

15. A microwave anechoic chamber according to claim 14, wherein said enclosure includes oppositely facing end walls, at least one of which is provided with a bulbous protuberance projecting from said wall into said room to reflect microwaves away from said quiet volume.

16. A microwave anechoic structure for housing means for propagating microwaves in one general direction and means for reflecting said microwaves in another general direction, comprising a plurality of walls assembled to define an enclosure, elongated re-entrant baffles formed on the inner surfaces of said walls, said baffles being large with respect to the wavelength of said microwaves and microwave absorbing material of relatively low decibel performance covering said walls and said baffles, a portion of said baffles having crest lines disposed generally lengthwise with respect to said one general direction and another portion of said baffles having crest lines disposed generally lengthwise with respect to said other general direction whereby extraneous microwaves are directed away from quiet volumes of relatively high decibel performance.

17. A microwave anechoic chamber according to claim 16, wherein said enclosure includes a pair of oppositely facing end walls, at least one of which is provided with an inwardly projecting protrusion to reflect electromagnetic energy away from an adjacent quiet volume.

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