United States Patent

Nakahara et al.

[15] **3,659,094**

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

[54] **MOVING OBJECT COMMUNICATION SYSTEMS**

[72] Inventors: **Tsuneo Nakahara; Noritaka Kurauchi; Hiroshi Kitani; Kenji Takemura**, all of Osaka, Japan

[73] Assignee: **Sumitomo Electric Industries, Ltd.**, Osaka, Japan

[22] Filed: **Mar. 31, 1970**

[21] Appl. No.: **24,240**

[30] **Foreign Application Priority Data**

Apr. 1, 1969 Japan....................................44/24365

[52] **U.S. Cl.** ....**246/1 R,** 246/30, 343/713, 343/717, 325/51, 325/52

[51] **Int. Cl.** **H01q 1/32**

[58] **Field of Search**...............246/8, 30; 343/18 A, 711, 712, 343/713, 717; 325/51, 52

[56] **References Cited**

UNITED STATES PATENTS

3,281,591 10/1966 Takeya ....246/30 X

3,290,626 12/1966 Hafner..................................246/8 X

2,538,035 1/1951 Pickles.............................343/18 A X

Primary Examiner—Arthur L. La Point

Assistant Examiner—George H. Libman

Attorney—Carothers and Carothers

[57] **ABSTRACT**

Radio interference of a moving object communication system, wherein radio communication is between ground stations and a moving object such as a train, with other communication systems which is caused by the electromagnetic coupling between a leaky waveguide and an antenna aboard the moving object, is greatly reduced by providing a ground structure supporting the leaky waveguide in such a way that a narrow space or channel is left between the ground structure and the body of the moving object adjacent the direct coupling space between the line and the antenna. An electromagnetic wave absorbing substance is provided in this narrow space or channel and further the channel is preferebly additionally provided with corners in order to attenuate unwanted interference with other communication systems.

7 Claims, 11 Drawing Figures

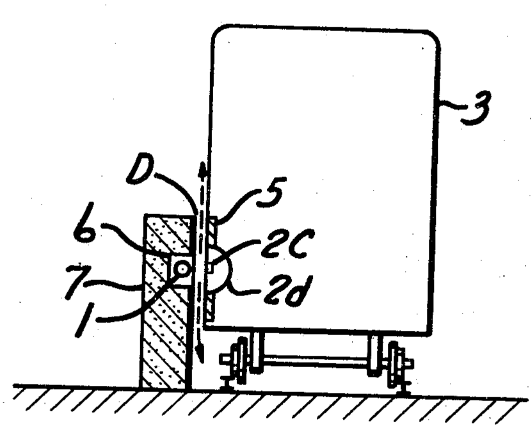


Fig. 1

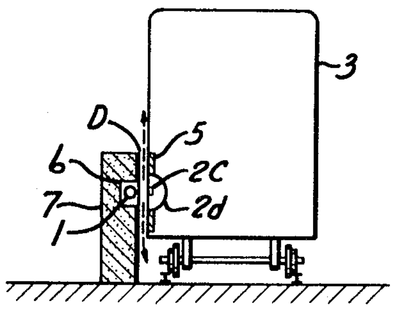


Fig. 3

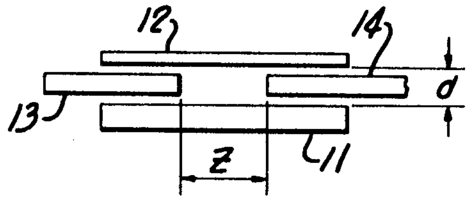


Fig. 2

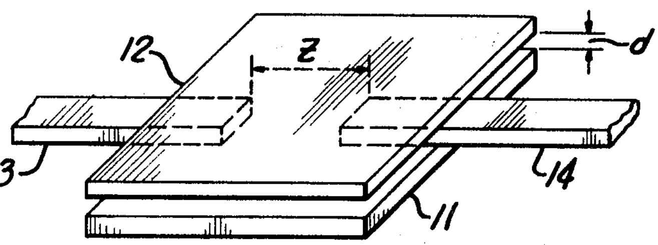
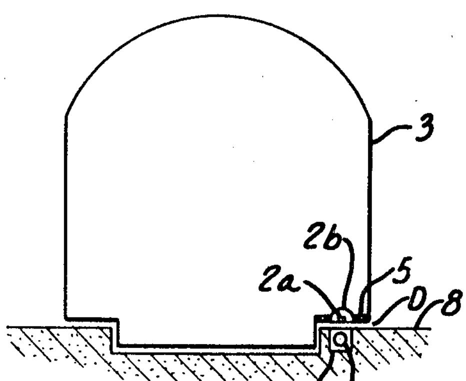
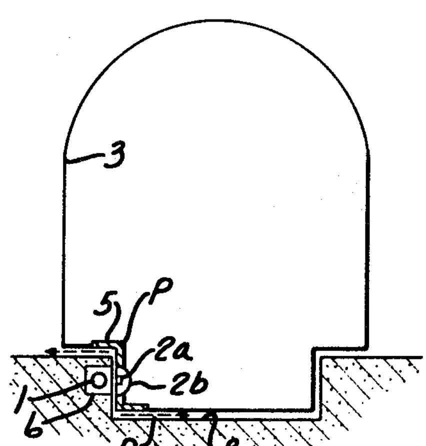


Fig. 7

Fig. 6





INVENTORS.
TSUNEO NAKAHARA, NORITAKA KURAUCH
HIROSHI KITANI & KENJI TAKEMURA
BY
CAROTHERS & CAROTHERS
THEIR ATTORNEYS

Fig. 4

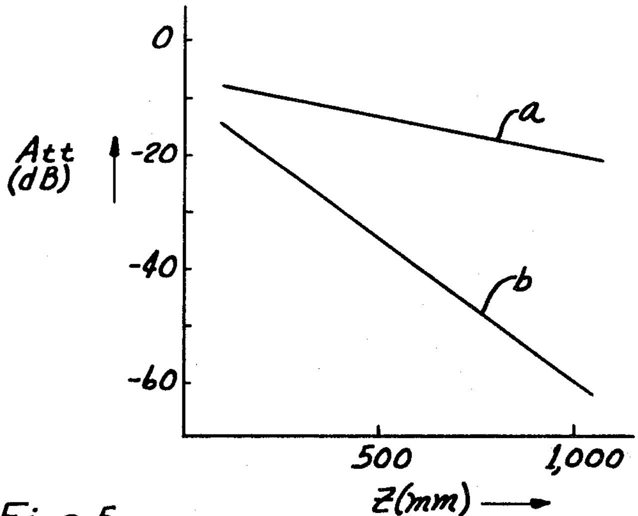


Fig. 5

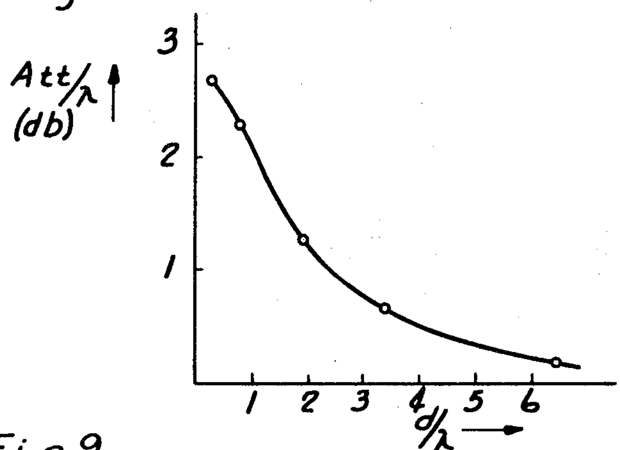
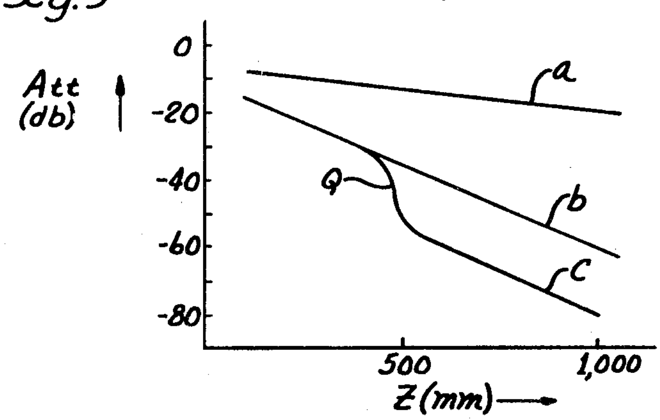


Fig. 9



INVENTORS.
TSUNEO NAKAHARA, NORITAKA KURAUCH
HIROSHI KITANI & KENJI TAKEMURA
BY
CAROTHERS & CAROTHERS
THEIR ATTORNEYS

Fig. 8

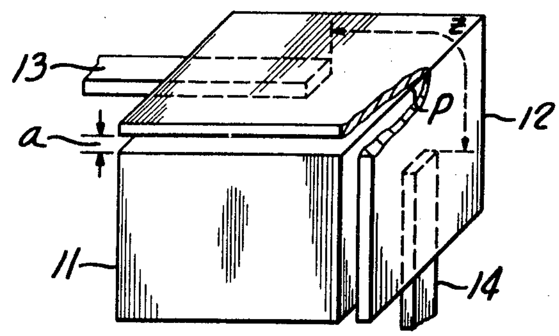


Fig. 10

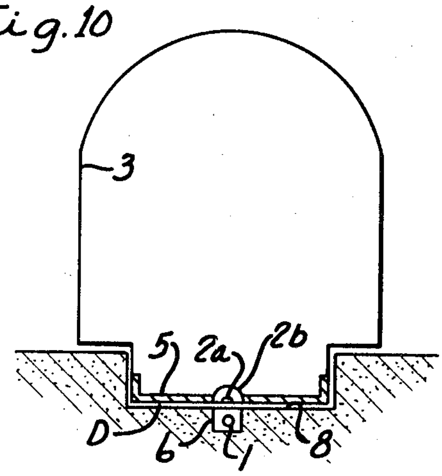
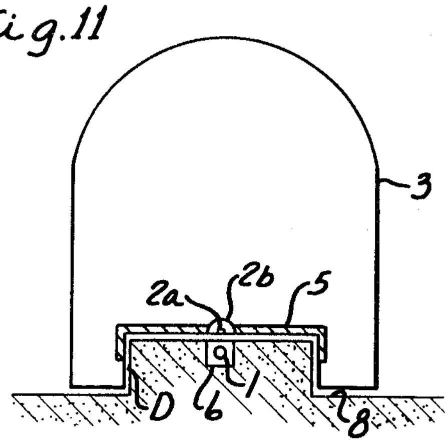


Fig. 11



INVENTORS.
TSUNEO NAKAHARA, NORITAKA KURAUCHI,
HIROSHI KITANI & KENJI TAKEMURA
BY
CAROTHERS & CAROTHERS
THEIR ATTORNEYS

MOVING OBJECT COMMUNICATION SYSTEMS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a communication system for moving objects such as trains.

2. Description of the Prior Art

Heretofore, in a train or moving object communication system, radio communication between ground stations and trains was done such that an electromagnetic wave of uniform intensity was radiated from a leaky wave guide connected to the ground stations along the rail road track and which was coupled with an antenna aboard a train. With such an arragement, however, unexpected interference waves from other commercial communication systems often intrude, while on the other hand waves from such a system interfere with other communication system because of their leaking from the place of coupling between the leaky wave guide and the antenna aboard the train.

Generally speaking, the interference noise level at the receiver on board the moving vehicle and which is connected to the train antenna, is very high or serious, while the interference noise level at the receiver located at the ground stations and connected to the leaky waveguide is not serious. The electromagnetic waves from other communication system couple strongly to the train antenna, while they couple weakly to the leaky waveguide because they greatly attenuate when they enter a waveguide.

SUMMARY OF THE INVENTION

The present invention has as a principle object, the reduction of interference between other communication systems and the train communication system, particularly such other systems found at a train station. In order to attain this object, the present invention uses a device which reduces the radiation power of electromagnetic waves eminating from the train antenna without affecting the degree of coupling between the train antenna and the leaky waveguide. As means to carry this out, two embodiment may be used in accordance with the teachings of the present invention.

The first means is performed by the absorption of electromagnetic waves which would radiate outwards in undesired directions from the train antenna by means of a wave absorbing substance disposed around the train antenna.

The second means is performed by the absorption of electromagnetic waves by way of attenuation due to diffraction of electromagnetic waves at a corner of a narrow space between a train body and a ground structure.

BRIEF EXPLANATION OF THE DRAWING

FIG. **1** is a diagrammatic sectional view showing the relationship between an antenna on a train and a leaky waveguide for the communication system of the present invention.

FIG. **2** is a diagrammatic perspective view of the measurement device for the explanation of the principle of the present invention.

FIG. **3** is a diagrammatic front elevation of the same device shown in FIG. **2**, and

FIG. **4** and FIG. **5** are characteristics graphs showing the results of measurements made from the afore-said measurement device.

FIG. **6** and FIG. **7** are diagrammatic sectional views in elevation showing other example embodiments.

FIG. **8** is also a diagrammatic perspective view of a measurement device for the explanation of the principles of the present invention.

FIG. **9** is a characteristics graph showing the measurement results.

FIG. **10** and FIG. **11** are diagrammatic sectional views in front elevation showing other examples of embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** shows an example embodiment of this invention according to the first aforementioned means.

In FIG. **1**, **1** denotes the leaky waveguide, **3** the main body of the train, **5** the electromagnetic wave absorbing substance disposed around the antenna, **6** the duct for the installation of the waveguide along the indicated tracks, and **7** a ground structure on the railroad track which supports the leaky waveguide and which is installed near to the train, for the object of this invention, to prevent the leakage of electromagnetic waves. The ground structure is made of such a material as metal, concrete, etc. which reflects electromagnetic waves or which absorbs electromagnetic waves to some degree, though not completely. **2c** and **2d** denote parts constituting the train antenna, **2c** being a primary radiator of the traveling wave type made of a rectangular waveguide, and **2d** being a secondary radiator made of a metal reflector having an elliptical cylinder shape. D is a narrow spacing between the train body **3** and the ground structure **7**.

The principle of the first example means of the present invention is that the electromagnetic wave radiated by the train antenna is transmitted well to the leaky waveguide in the duct **6**, but that portion which is apt to pass through the narrow channel region defining space D between the ground structure **7** and the electromagnetic wave absorbing substance **5** disposed around the antenna on the train body as shown by the arrows of the broken lines, is subjected to great attenuation. Thus, the amount of electromagnetic wave radiation directed outwards becomes very small.

It should be noted that the width of the narrow channel region, as defined by the width of the electromagnetic wave absorbing substance **5**, is significant, meaning that it is of sufficient width such that the wave absorbing material can effectively attenuate the electromagnetic waves passing through the channel region.

Now a model experimental apparatus for confirming this attenuation of the outwardly directed electromagnetic waves will be explained. FIG. **2** is a perspective view of the experimenting apparatus. FIG. **3** is its front elevation. Rectangular waveguides **13, 14** are placed between planes of metal **11** and **12**, the appertures of the waveguides being opposed at the distance Z to each other. The distance between **11** and **12** is represented by *d*. The rectangular waveguide **13** is connected to an oscillator and the rectangular waveguide **14** to a receiver. The distance between their appertures is represented by Z.

With the above-described apparatus, the rectangular waveguide **13** on the transmission side is fixed and the rectangular waveguide **14** on the receiver side is moved forward and back to vary the distance Z between the appertures of the two waveguides, and the changes in the amount of attenuation of electromagnetic waves with respect to distance Z are measured.

FIG. **4** shows the results of the above-mentioned measurements. In that figure, the abscissa is the distance Z, expressed in mm, between the appertures of the transmitting and receiving rectangular waveguides, while the ordinate is attenuation between the transmitting and receiving waveguide. The curve-*a* represents the results when metal was used for both **11** and **12** of FIG. **2** and FIG. **3**, while the curve-*b* represents the results when metal was used for **11** and an electromagnetic wave absorbing substance was used in place of metal for **12**, with the frequency at the time of measurement being 10 GH_z, and the distance between metals **11** and **12**, $d = 20$ mm.

From these measurement results, it is obviously noted that the attenuation with the curve-*b*, using an electromagnetic wave absorbing substance on one side, is much greater than that with the curve-*a* using metal on both sides, and that an electromagnetic wave is subject to great attenuation when passing through a space between a metal plate and electromagnetic wave absorbing substance.

FIG. 5 shows the results of measurement of the variations in the attenuation of an electromagnetic wave versus the distance d between the metal plate **11** and the electric wave absorbing substance **12**, while keeping a constant distance Z between the appertures of the aforementioned rectangular waveguides **13** and **14**. The ratio of the distance d to the wavelength λ, d/λ, is shown on the abscissa and the ratio of the attenuation, A*tt*, to the wavelength λ, Att/λ, is shown on the ordinate.

According to FIGS. **4** and **5**, it is noted that when the distance d between the metal plate and the electromagnetic wave absorbing substance is much shorter than the wavelength, the attenuation is great, so that it is highly effective. Attenuation of 2.7 db per wavelength is obtained when $d = \lambda/3$. To the contrary, as d becomes much longer than the wavelength, attenuation per wavelength decreases. When $d = 3\lambda$, the attenuation is 0.5 db per wavelength and when $d = d = 6\lambda$, it is 0.1 db.

If the traveling length of the electromagnetic wave in the gap between (**11**) and (**12**) is assumed to be 1,000 mm and $\lambda = 30$ mm, A then = 3 db when $d = 6\lambda$ and A = 15 db when $d = 3\lambda$. Technically, it is desirable that there be an attenuation of more than 10 db. For this reason, a distance d of 4λ or less is suitable.

As described above, electromagnetic waves can be attenuated effectively by making the distance small between the electromagnetic wave absorbing substance and the metal body.

What has been mentioned above refers to the utilization of the attenuation of electromagnetic waves by reducing the distance between the electromagnetic wave absorbing substance and the metal object to 4λ or less. If the electromagnetic wave absorbing substance is used in place of the other metal body also, the effective utilization of the attenuation of electromagnetic waves can be made until the distance between the electromagnetic wave absorbing substance and the other electromagnetic wave absorbing substance reaches two times 4λ, i.e. 8λ, because of the principle of mirror image. The reflection coefficient of concrete is −13 db. This is larger than the reflection coefficient −26 db of an ordinary electromagnetic wave absorbing substance. In this case, however, a similar effect was obtained where the distance was 6λ or less. Now a substance such as concrete, which is somewhat less effective in the absorption of electromagnetic waves, is called a semi-electromagnetic wave absorbing substance, and the metal plate is called wave reflecting substance.

FIG. 6 shows an example embodiment wherein the system of the present invention based, on the above-described measurement results, is made applicable to an air or magnetic suspension train which is expected to be developed in the future.

In FIG. 6, **1** denotes a leaky waveguide, **2*a*** and **2*b*** the primary and secondary radiators of the train antenna respectively, **3** the main body of the train, **5** and electromagnetic wave absorbing substance, **6** a duct to house the leaky waveguide, and **8** the road floor made of concrete or the like. In this case, the spacing between the train and the road floor will be made very small, so that the train antenna and the electromagnetic wave absorbing substance can be brought very near to the road floor. Electromagnetic waves radiated from the train antenna to the outside through space D attenuate very greatly.

The second means of the present invention consists in the utilization of attenuation due to diffraction of electric waves, at a corner of the narrow space between train body and a ground structure or floor. An embodiment of the present invention according to the second means is shown in FIG. 7.

In case the device according to the present invention is used, the electromagnetic waves radiated from the train antennas **2*a*** and **2*b*** couple directly with the waveguide **1** and at the same time part of them are radiated outward through the space between the road floor **8** and the electromagnetic wave absorbing substance **5**. Unlike the aforementioned space, this space is provided with a corner P, and the present invention takes advantage of the attenuation which occurs when electromagnetic waves diffract at this corner. The results of experimental measurement of the attenuation of electromagnetic waves at such a corner are shown hereinafter.

FIG. **8** shows an apparatus for this experiment. **11** is a metal body, **12** an electromagnetic wave absorbing substance, **13** a rectangular waveguide on the transmission side, and **14** a rectangular waveguide on the receiving side, the appertures of these waveguide being spaced at the distance Z. Point P is, as in FIG. 7, the corner of the electromagnetic wave passage of an electromagnetic wave absorbing substance. While an electromagnetic wave comes out from the rectangular waveguide **13** on the transmission side, passes the part P and reaches the rectangular waveguide **14** on the receiving side, it undergoes great attenuation.

The results of measurement by the above-mentioned experiment are shown in FIG. **9**. In that figure, the abscissa represents the distance Z between the appertures of the waveguides on the transmission and the receiving side, expressed in millimeters. The ordinate represents the degree of attenuation, A*tt* of, electromagnetic waves, expressed in decibels. The curve-*a* and curve-*b* of FIG. **4** are transcribed on FIG. **9** for reference, the curve-*a* showing attenuation for waves passing between two metal bodies and the curve-*b* showing the attenucation of waves passing between a metal body and an electromagnetic wave absorbing substance. The curve-*c* shows the results of measurement made by the aforementioned apparatus shown in FIG. **8**. The part-Q of the curve-*c* shows the attenuation due to the bend of the electromagnetic wave passage, i.e. part-P as shown in the FIG. **8**. The attenuation due to the corner, namely the difference between the curve-*b* and the curve-*c* at the part-Q, amounts to approximately 20 db for the wave of a wavelength of 30 mm. This remarkable amount of attenuation is very suitable for the purpose of the present invention. According to the results of experiment, the amount of attenuation due to the corner is very much greater than that due to the reduction of the distance d between the metal body and the electromagnetic wave absorbing substance.

As mentioned above, increasing the attenuation of electromagnetic waves is effected by providing a corner in a space between the train body and the ground structure as shown in FIG. 7. In addition to the attenuation created by a corner, great attenuation will also be obtained, as already stated, in a rectilinear passage, if the space is made small.

FIG. 10 and FIG. 11 show other examples of embodiment of the present invention. In both examples of the two figures, corner portions channeling electromagnetic waves are provided in the space between the electromagnetic wave absorbing substance **5** and the road floor **8**.

In these examples, one corner is provided in the space to either side of the antenna. However such a corner shall not be limited to one, but the greater the number of such corners provided in the space between the train and ground structure is, the more effective it will be to increase attenuation.

The first and the second means of this invention have been described in detail. If this invention is used, electromagnetic waves emitting from a train antenna are prevented from useless radiation from the train communication system by installing an electromagnetic wave absorbing substance in the neighborhood of the antenna aboard the train, thus eliminating interference between the train communication systems and other communication system.

In the aforementioned examples of the embodiment, electromagnetic wave absorbing substance is placed only in the neighborhood of the antenna aboard the train. However, it should not necessarily be installed on the train. It goes without saying that the same effect can be obtained also by installing such a substance in the neighborhood of the waveguide on the ground or in the neighborhood of both.

Throughout the foregoing description, a leaky waveguide has always been used for the transmission line on the ground for train communication. However, the present invention is not to be limited to systems where a leaky waveguide is used. It is equally applicable to systems using a leaky coaxial cable, which is a coaxial cable provided with leaky apperture, or a surface wave line, or the like. Such lines shall therefore be given a generic name hereinafter as an open type transmission line.

What we claim is:

1. A communication coupling system for a moving vehicle following a predetermined path, comprising a support structure following said path and supporting a continuous open-type transmission line therealong spaced adjacent to an antenna mounted on a vehicle on said path for movement thereover and continuously providing an electromagnetic coupling space between said line and said antenna while said vehicle is in motion, said support means providing a continuous reflective or semi-electromagnetic wave absorbing surface behind said transmission line opposite to said coupling space, the surfaces of said support structure and said vehicle defining a closely spaced channel region therebetween of significant width and at least coextensive with said antenna on at least one side of said electromagnetic coupling space, at least one of the surfaces in said channel region including electromagnetic wave absorbing material to attenuate electromagnetic waves passing through said channel region.

2. The communication coupling system of claim 1 wherein said channel region spacing is maintained to be no greater than approximately eight wavelengths of the electromagnetic wave in use for coupling between said line and said antenna.

3. The communication coupling system of claim 2 characterized in that said closely spaced channel region passes through at least one corner.

4. The communication system of claim 2 wherein both of the opposed surfaces of said channel include electromagnetic wave absorbing properties.

5. The communication coupling system of claim 2 wherein said channel region extends from both sides of said coupling region between said support structure and said vehicle to attenuate all electromagnetic waves escaping from said coupling space.

6. The communication system of claim 2 wherein said wave absorbing means is capable of attenuation of said electromagnetic waves passing through said channel region of more than 10 db.

7. The communication system of claim 1 wherein only one of said channel surfaces has electromagnetic wave absorbing properties and the spacing between said surfaces of said channel region is maintained at no more than four wavelengths of the wavelength in use.

* * * * *