Nov. 17, 1964 R. M. WHITE 3,157,845

RECTANGULAR TO RIDGED WAVEGUIDE TRANSITION HAVING SEPARATE MODE CONVERTING AND IMPEDANCE MATCHING SECTIONS

Filed Jan. 29, 1963 3 Sheets-Sheet 1

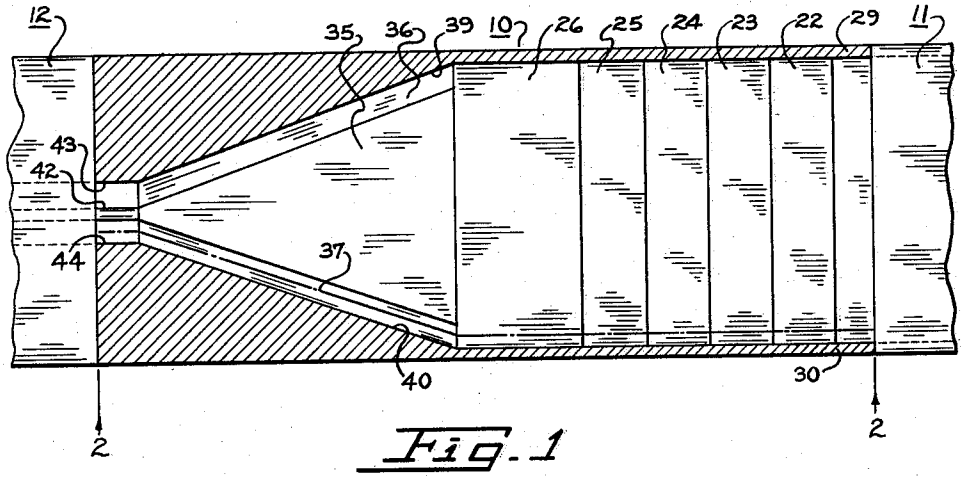


Fig. 1

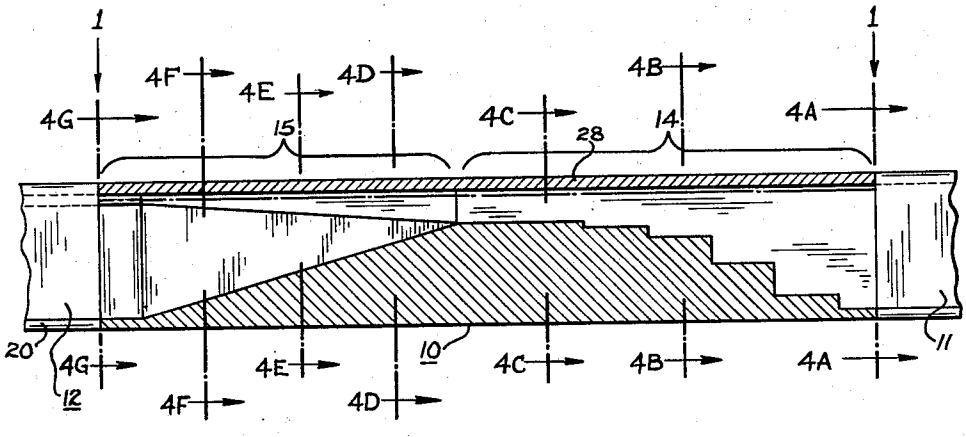


Fig. 2

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Filed Jan. 29, 1963 3 Sheets-Sheet 2

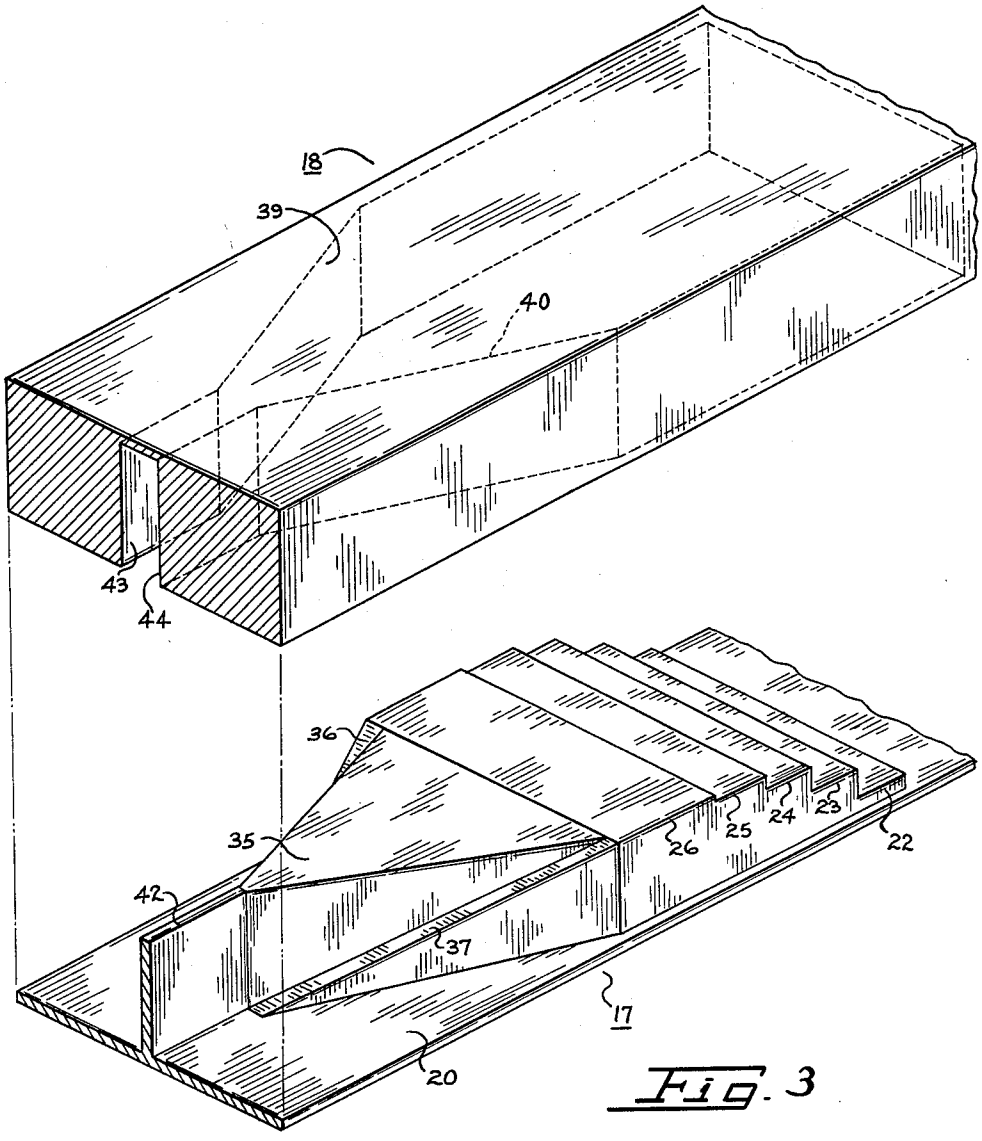


Fig. 3

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Filed Jan. 29, 1963 3 Sheets-Sheet 3

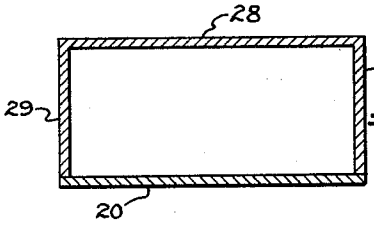


Fig. 4A

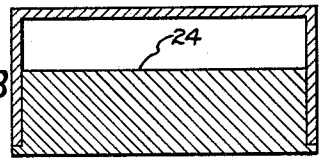


Fig. 4B

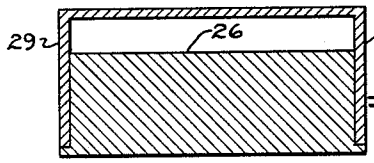


Fig. 4C

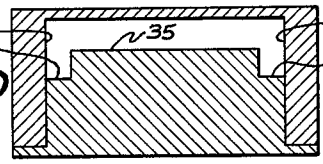


Fig. 4D

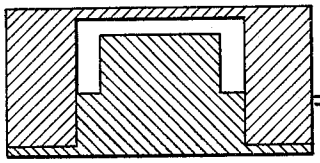


Fig. 4E

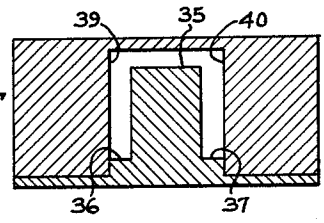


Fig. 4F

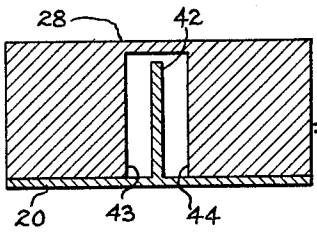


Fig. 4G

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3,157,845

RECTANGULAR TO RIDGED WAVEGUIDE TRANSITION HAVING SEPARATE MODE CONVERTING AND IMPEDANCE MATCHING SECTIONS

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7 Claims. (Cl. 333—21)

This invention relates to waveguide transmission devices and more particularly to transitions for transferring microwave energy between a rectangular waveguide and a ridged waveguide.

It is often useful to employ different microwave waveguides in the same system for transmitting microwave energy. The employment of different waveguides makes most effective use of the respective mechanical and electrical properties of the waveguides. For example, it is often desirable to use both rectangular and ridged waveguides, because ridged waveguide, although more expensive and difficult to manufacture than rectangular waveguide, is characterized by certain advantages over rectangular waveguide including a broader bandwith, a longer cut-off wavelength for a given waveguide size, and a lower characteristic impedance.

In such a system it is necessary to provide transitions for transferring microwaves from rectangular waveguides to ridged waveguides, from ridged waveguides to rectangular waveguides, or in both directions between rectangular and ridged waveguides. To make best use of the capabilities of both types of waveguides, the transition should provide for the lossless transfer of microwaves over a broad frequency range and should effect such transfer without substantial reflection of the microwaves incident on the transition. Additionally, it is desirable for the transition to be compact, easily and accurately designed, and readily machined. The structure of such a transition is complicated by the necessities of providing a smooth transformation of impedance between the two types of waveguides to be coupled and of providing for the reorientation of the field configurations in the two waveguides. The transitions heretofore available, however, have usually been subject to a number of disadvantages because the two functions of impedance transformation and field reorientation have been intermingled. These prior art devices have been difficult to design and fabricate. Thus, these prior art devices have proven unduly costly and have not always effectively provided the broadband reflection-free transmission desired.

Therefore, it is the principal object of this invention to provide an improved microwave transition.

Another object of this invention is to provide an improved microwave transition for coupling a rectangular waveguide to a ridged waveguide.

Another object of this invention is to provide an improved microwave transition for coupling a rectangular waveguide to a ridged waveguide, operable over a broad frequency range and without substantial wave reflection.

Another object of this invention is to provide an improved microwave transition for coupling a rectangular waveguide to a ridged waveguide that is more compact, simpler to design, and easier to fabricate than prior art transitions.

The foregoing objects are achieved by providing a microwave transition for coupling a rectangular waveguide to a ridged waveguide wherein the functions of impedance transformation and field reorientation are separated in cooperatinng sections. The transition comprises a hollow waveguide first section of uniform width coupled at one end to the rectangular waveguide and a tapered ridged waveguide second section coupled at one

end to the ridged waveguide, the two sections being joined together at their free ends. The height of the first section decreases by steps along the length thereof to transform from the characteristic impedance of the rectangular waveguide to that of the ridged waveguide. The height of the ridge in the second section continuously increases and the width of the ridge continuously decreases along the length of the second section, so as to maintain the characteristic impedance substantially constant while providing for a smooth reorientation of the field configuration from that in the first section to that in the ridged waveguide. The design of such a transition to provide broadband operation without substantial reflection is simplified by the separated regions of impedance transformation and field reorientation. Furthermore, the transition is compact, simple to design, and easy to fabricate.

The invention will be described with reference to the following drawings, wherein:

FIGURE 1 is a top view, partly in cross-section, of the transition of this invention;

FIGURE 2 is a front elevational view, partly in cross-section of the transition of FIG. 1;

FIGURE 3 is an exploded view of the transition of FIGS. 1 and 2; and

FIGURES 4A–4G are cross-sectional views of the transition of FIGS. 1 and 2.

The transition 10 of the figures is illustrated as providing for the transmission of microwaves in both directions between a rectangular waveguide, denoted generally by the reference numeral 11, and a ridged waveguide denoted generally by the reference numeral 12. Transition 10 comprises a first section 14 and a second section 15. One end of first section 14 is joined to rectangular waveguide 11 and one end of second section 15 is joined to ridged waveguide 12. The other ends of sections 14 and 15 are joined together. In the figures, waveguides 11 and 12 and sections 14 and 15 are shown formed as a unitary structure; however, it is within the scope of the instant invention to provide that such waveguides and sections are separable and adapted for joining together by conventional techniques, such as by the employment of mating flanges on the coupling ends.

It is the function of first section 14 to provide a progression of characteristic impedance changes therein, such that the characteristic impedance of the section at one end thereof is equal to the characteristic impedance of waveguide 11 and at the other end thereof is equal to the characteristic impedance of waveguide 12. These changes in characteristic impedance are designed to provide for the transmission therethrough of microwaves over a broadband of frequencies without substantial reflection. It is the function of second section 15 to provide for the smooth transformation, or reorientation, of the field configuration from that present in section 14 to that present in ridged waveguide 12. Accordingly, section 15 provides a smooth variation in cross-sectional geometry from one end to the other end thereof, the characteristic impedance and cut-off wave length remaining substantially constant as the field configuration is altered from that of a rectangular waveguide of low height to that of the ridged waveguide 12.

The illustrated embodiment of transition 10 is formed of a base member 17 and a cap member 18. Base member 17 is provided with a base plate 20 on which are formed or to which are affixed upwardly extending steps and ridges to be described hereinafter. Cap member 18 fits over the upwardly extending steps and ridges of base member 17 and the bottom surface of cap member 18 is brazed or otherwise affixed to the opposing portions of the upper surface of base plate 20. Thus, the combined structure of base member 17 and cap member 18 defines a portion of rectangular waveguide 11 at

one end thereof, a portion of ridged waveguide **12** at the other end thereof, and first section **14** and second section **15** between such end portions.

First section **14** comprises a plurality of conductive steps, such as steps **22**, **23**, **24**, **25**, and **26**, disposed within a rectangular waveguide portion comprising base plate **20**, top wall **28** and side walls **29** and **30**. Section **14** provides a transformation for matching the relatively low characteristic impedance of ridged waveguide **12** and second section **15** to the relatively high characteristic impedance of rectangular waveguide **11**. The height of step **26** is adjusted to provide the rectangular waveguide portion defined by the upper surface of step **26**, top wall **28**, and side walls **29** and **30** with a characteristic impedance equal to that of ridged waveguide **12**. The number of steps employed in section **14** is determined by the impedance transformation required, the desired bandwidth of transmission, and the maximum amount of reflected microwave energy which can be tolerated from section **14**. Details of the design of a particular first section **14** will be described hereinafter. Each of steps **22–26** extends across the entire interior width of section **14**.

Second section **15** comprises a tapered ridge **35** partially sandwiched between a pair of shoulders **36** and **37**. Ridge **35** and shoulders **36** and **37** are disposed within a tapered waveguide portion defined by base plate **20**, top wall **28**, and inwardly tapering side walls **39** and **40** of cap member **18**. One end of ridge **35** is affixed to, or joins, one end of step **26**. The other end of ridge **35** connects to, or joins, ridge **42** of ridged waveguide **12**. The height of ridge **35**, at its junction with step **26** is the same as the height of step **26**. Ridged waveguide **12** comprises base plate **20**, ridge **42**, top wall **28**, and side walls **43** and **44** of cap member **18**. The height of ridge **35**, at its junction with ridge **42** is equal to the height of ridge **42**. Therefore the height of ridge **35** continuously increases in a direction along the length of section **15** from its value where it joins step **26** to its value where it joins ridge **42**.

The height of shoulders **36** and **37** continuously decrease along the length of section **15**, from a height equal to that of step **26**, where they abut. The shoulders terminate with no height at the entrance to ridged wageguide **12**. Thus two channels are formed on each side of ridge **35**. One channel is defined and bounded by one side of ridge **35**, the upper surface of shoulder **36** and side wall **39**. The other channel is defined and bounded by the other side of ridge **35**, the upper surface of shoulder **37** and side wall **40**. Each of these channels continuously increases in depth along the length of section **15** because of both the decrease in height of shoulders **36** and **37** and the increase in height of ridge **35**. These two channels comprise the two stems of a tapered ridged waveguide. The region between the upper surface of ridge **35** and top wall **28** defines the upper cross portion of the tapered ridged waveguide. Therefore ridge **35**, shoulders **36** and **37**, side walls **39** and **40** and top wall **28** define a ridged waveguide along the length of second section **15**, the height of such ridged waveguide continuously increasing and the width of such ridged waveguide continuously decreasing along the length of section **15** from step **26** to ridge **42**. At the entrance to ridged waveguide **12** the internal dimensions of the tapered ridged waveguide are equal to those of ridged waveguide **12**, so that at this point the width of ridge **35** is equal to the width of ridge **42** and the distance between side walls **39** and **40** is equal to the distance between side walls **43** and **44**.

Thus, section **15** provides a tapered ridged waveguide for transforming, or reorienting, the electromagnetic field from the configuration existing in section **14** immediately above step **26** to the configuration existing in ridged waveguide **12**. Thus section **15** transforms the field configuration from the relatively simple pattern in section **14**, wherein all electric field vectors are directed vertically and all magnetic field vectors are directed horizontally, into the complex pattern required to satisfy the boundary conditions of ridged waveguide **12**. This transformation is effected over a broadband of frequencies without substantial losses or reflection by tapering the ridged waveguide in section **15** such that the characteristic impedance thereof remains substantially constant and equal to that of ridged waveguide **12** and such that the cut-off wavelength remains substantially constant. Details of the design of a particular second section **15** will be described hereinafter.

Thus has been described a novel and improved transition for coupling a rectangular waveguide to a ridged waveguide wherein microwave energy is transmitted between the two waveguides over a broad frequency range without substantial reflection. The transition described is also more compact, simpler to design, and easier to fabricate than prior art devices for accomplishing the same function.

The design of a particular transition will now be described. This transition is intended to couple a rectangular waveguide having an internal width of .900" and an internal height of .400" to a ridged waveguide having an internal width of .202" and an internal height of .400". The ridged waveguide has a single ridge affixed to the lower wall, the ridge having a height of .370" and a width of .030". The transition is designed to transmit, without substantial attenuation or reflection, microwaves in the frequency range of 7.8 to 10.3 kilomegacycles (kmc.). To minimize the wave reflection, four intermediate steps **22–25** are employed in section **14**. Fewer steps may be used, although the degree of reflection increases as the number of steps decreases. The theoretical characteristic impedance of the rectangular waveguide **11** is computed to be 339 ohms for infinite frequency. The corresponding characteristic impedance for the ridged waveguide **12** is computed to be 98 ohms. The height of step **26** is designed to provide the same characteristic impedance as that of the ridged waveguide; the height of a rectangular waveguide for an infinite frequency characteristic impedance of 98 ohms is computed to be .116". Therefore the height of step **26** is .284". Accordingly, first section **14** is designed to provide an impedance transformation ratio of 339:98, or 3.47. Finally, to provide a factor of safety a bandwidth of 0.80 is employed in the design.

Once the specifications have been decided, the step heights may be computed, such as by employing the design tables of L. Young, "Tables for Cascaded Homogeneous Quarter-Wave Transformers," IRE Transactions on Microwave Theory and Techniques, pages 233 to 237, April 1959, and pages 243, 244, March 1960. Thus, for a four-step transformer to provide a transformation ratio of 3.47 over an 0.80 bandwidth the design tables of the Young article specify the following step heights.

Step number:	Inches
22	.045
23	.138
24	.224
25	.270

From the Young article a design length for each step is suggested as one-quarter guide wavelength; this length being defined in the article. A first section **14**, constructed according to the above design provides the requisite impedance match over the design frequency range with a minimum of reflected waves.

Second section **15** is adapted to provide for the transformation of the microwave field. The height of ridge **35** at the end adjacent step **26** is equal to the height of step **26**. The height of ridge **35** adjacent ridge **42** is the same as that of ridge **42**. The height of ridge **35** between step **26** and ridge **42** has a constant slope, so that the upper surface of ridge **35**, as seen in FIG. 2, represents a straight line connecting the tops of step **26** and ridge **42**. The width of ridge **35** is determined by the widths of shoulders **36** and **37**. The width of each of these shoulders is con-

stant and equal to the distance between a side of ridge 42 and the opposing one of side walls 43 and 44. The height of shoulders 36 and 37 at the ends adjacent step 26 is equal to the height of step 26. At their other ends the height of these shoulders diminishes to zero. Thus, in FIG. 2, the upper surface of shoulder 37 represents a straight line connecting the top of step 26 and base plate 20. The length of second section 15 should be at least one guide wavelength, wherein the guide wavelength is the wavelength of the microwaves in traveling along section 15. By maintaining a substantially linear increase in height and decrease in width of ridge 35 between step 26 and ridged waveguide 12, the characteristic impedance and cut-off wavelength remain substantially constant along the length of second section 15. The constant characteristic impedance of section 15 is equal to that of ridged waveguide 12. The cut-off wavelength of section 15 is equal to that of both rectangular waveguide 11 and ridged waveguide 12. The cut-off wavelength in the tapered ridged waveguide is proportional to the mean distance from the upper surface of shoulder 36 over the top of ridge 35 to the upper surface of shoulder 37.

Accordingly, the unitary combination of first section 14 and second section 15 is a simply designed and easily fabricated transition between rectangular and ridged waveguide, providing for the transfer of microwaves therethrough over a broad frequency range without substantial attenuation or reflection.

While the principles of the invention have been made clear in the illustrative embodiments, there will be obvious to those skilled in the art, many modifications in structure, arrangement, proportions, the elements, materials, and components, used in the practice of the invention, and otherwise, which are adapted for specific environments and operating requirements, without departing from these principles. The appended claims are therefore intended to cover and embrace any such modifications within the limits only of the true spirit and scope of the invention.

What is claimed is:

1. A transition for coupling a rectangular waveguide to a ridged waveguide comprising first and second sections joined together; said first section comprising a hollow rectangular waveguide portion and a plurality of conductive steps disposed within and along the length of said portion, each of said steps extending between a set of opposite walls of said portion, the height of each of said steps being greater than the heights of the preceding step in a direction along the length of said first section from one end to the other end thereof, the height of the step closest to said other end of said first section providing a characteristic impedance for said other end substantially equal to the characteristic impedance of said ridged waveguide, the internal cross-section of said first section at said one end thereof being the same as the internal cross-section of said

rectangular waveguide; said second section comprising a hollow outer member and a ridged member disposed within said outer member, said outer member continuously decreasing in internal width and continuously increasing in internal height in a direction along the length of said second section from one end to the other end thereof, said ridge member continuously decreasing in width and continuously increasing in height in said direction along the length of said second section, the internal cross-section of said second section at said other end thereof being the same as the internal cross-section of said ridged waveguide; and said one end of said second section being joined to said other end of said first section.

2. The transition of claim 1 wherein the width of said first section is uniform.

3. The transition of claim 2 wherein the internal widths of said one end of said second section and said other end of said first section are equal.

4. The transition of claim 3 wherein the internal heights of said one end of said second section and said other end of said first section are equal.

5. The transition of claim 4 wherein the cut-off wavelengths of said rectangular waveguide and said ridged waveguide are substantially equal.

6. The transition of claim 5 wherein all cross-sections of said second section have the same theoretical cut-off wavelengths.

7. A transition for coupling a rectangular waveguide to a ridged waveguide comprising first and second sections coupled together; said first section comprising a hollow rectangular waveguide portion, the height of said portion progressively decreasing in a direction along the length of said first section from one end to the other end thereof, the internal cross section of said first section at said one end thereof being the same as the internal cross section of said rectangular waveguide; said second section comprising a hollow outer member and a ridged member disposed within said outer member, said outer member decreasing in internal width and increasing in internal height in a direction along the length of said second section from one end to the other end thereof, said ridged member decreasing in width and increasing in height in said direction along the length of said second section, the internal cross section of said second section at said other end thereof being the same as the internal cross section of said ridged waveguide; and said one end of said second section being joined to said other end of said first section.

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