United States Patent

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[73] Assignee **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**

[54] **WAVEGUIDE MIXER**
12 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** ..... **325/445,** 329/161, 329/162, 332/51 W, 333/73 W, 343/772, 343/773, 343/786
[51] **Int. Cl.** **H01p 5/00**
[50] **Field of Search** ..... 325/445, 446; 329/161, 162; 332/51 W; 333/73 W; 343/772, 773, 786

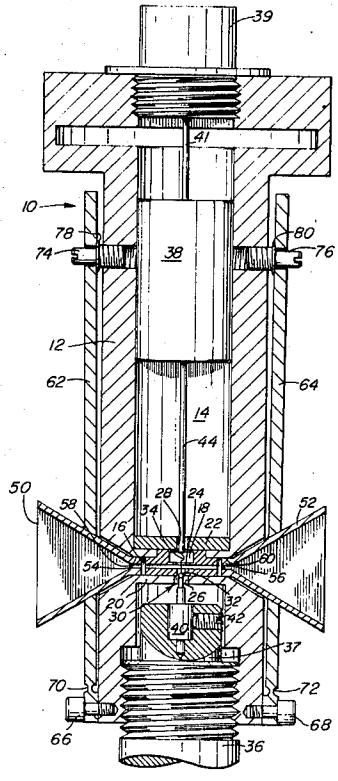
[56] **References Cited**

UNITED STATES PATENTS

2,436,830	3/1948	Sharpless	325/445
2,438,521	3/1948	Sharpless	325/445
2,455,657	12/1948	Cork et al.	325/445
2,673,930	3/1954	Matare	329/161
2,754,416	7/1956	Hope	325/446
2,832,885	4/1958	Brett	325/445 X
2,834,876	5/1958	Pritchard et al.	325/445
2,871,353	1/1959	Friis et al.	325/445
3,071,729	1/1963	Schiffman	325/446
3,169,224	2/1965	Butson	325/446
3,553,584	1/1971	Walsh	325/446 X

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ABSTRACT: A microwave mixer comprised of crossed waveguides and a crystal mixer. One of the waveguides has input horns at each end which are axially adjustable with respect to the ends of the waveguide. Axial adjustment of a horn with respect to the end of a waveguide varies the width of the gap between the horn and the waveguide to tune the signal input from the horn to the mixer. Accordingly, the mixer may be tuned by adjusting the position of the input horns with respect to the input ports of the mixer.



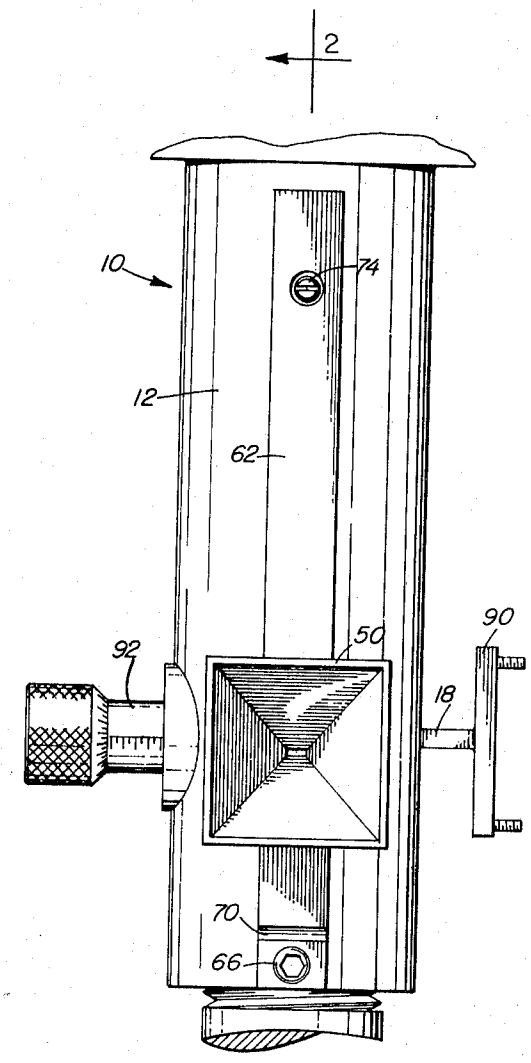


Fig. 1

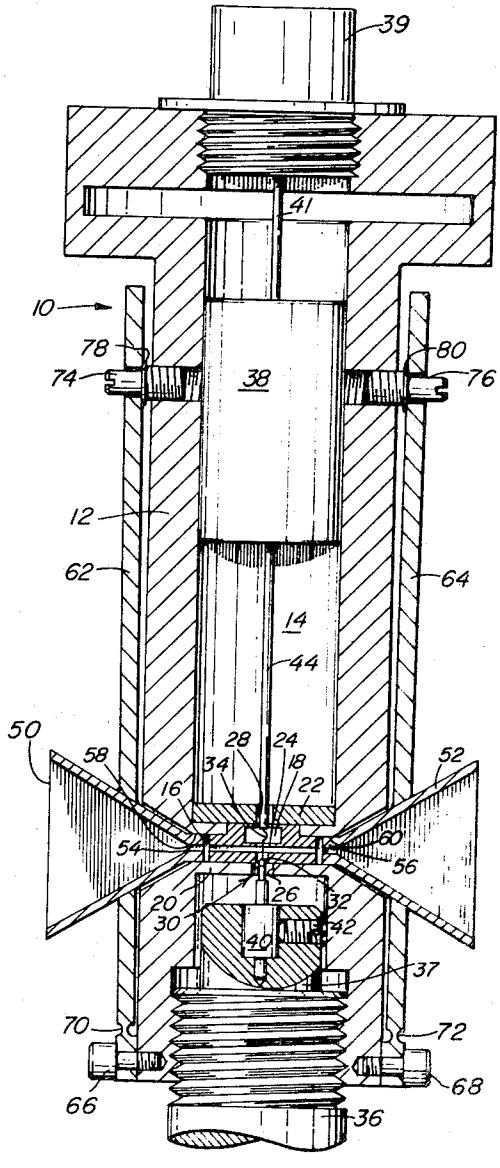


Fig. 2

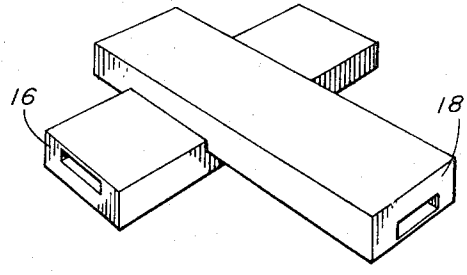


Fig. 3

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WAVEGUIDE MIXER

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of waveguide technology and is more particularly directed to microwave mixers employing crossed waveguide sections.

2. Description of the Prior Art

The prior art microwave harmonic multipliers and mixers generally employ a crossed waveguide configuration in which the waveguides share a common wall at the crossover junction with a transfer aperture in the central portion of the common wall. Microwave energy is supplied to a first of the waveguides and may be coupled to the second of the waveguides by means of a crystal mixer. The crystal mixer includes a "diode" with a cat's whisker extending from the "diode" through the transfer aperture into the second waveguide. The diode may be any one of several materials e.g. silicon, germanium, steel, nickel. etc.

Efficient transfer of the input signal into the mixer is accomplished by forming an integral pyramidal horn inside the input end of the first waveguide. A tuning stub is installed in the opposite end of the first waveguide and may be adjusted within the opposite end to tune the input signal to the mixer. A crossed waveguide device of this type is disclosed in the article by Bauer et al., "Millimeter Wave Semiconductor Diode Detectors, Mixers, and Frequency Multipliers," Proceedings of the IEEE, Volume 54, No. 4, pp. 595, Apr. 1966.

In the crossed waveguide mixers, the number of inputs is limited to one input signal per waveguide since the tuning stub blocks the one end of the waveguide. If the tuning stub is removed, it is possible to add a second input signal per waveguide; however, the removal of the stub eliminates the ability to tune the mixer to different input frequencies.

It is accordingly an object of the present invention to disclose an improved crossed waveguide device which can be employed for mixing more than two microwave input signals.

It is a further object of the present invention to disclose a crossed waveguide device in which a plurality of microwave signals can be mixed and each of the signals can be individually tuned for maximum coupling efficiency.

It is a further object of the present invention to disclose a microwave mixing device which is simple in construction and easily tuned to several input signals having different frequencies.

SUMMARY OF THE INVENTION

The invention relates to a crossed waveguide device which can be tuned to several different input signal frequencies. The first waveguide crosses over the second and has an interconnecting transfer aperture through the common wall of the waveguide at the intersection. Two pyramidal horns are associated with the respective ends of the first waveguide and are axially adjustable with respect to the ends so that a tuning cavity between the confronting ends of the horn and the waveguide can be tuned to the input signals supplied through the horns. In a similar manner, another input may be connected to one end of the second waveguide so that a third input signal can be combined with inputs from the first waveguide.

Each of the input signal horns connected to the waveguide is individually supported by a leaf spring which can be flexed with respect to the coupler housing. Displacement of the spring adjusts the tuning cavities between the horns and the respective ends of the waveguides. Fine adjustment of the leaf spring is permitted by a screw which displaces the leaf spring and horns over distances of a few thousandths of an inch.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel microwave mixer will be better understood together with its numerous objects and advantages by reference to the following drawings wherein the same elements are identified by the same reference numeral throughout the several figures.

FIG. 1 is an external lateral view of the waveguide mixer as seen along the axis of one of the pyramidal signal input horns.

FIG. 2 is a cross-sectional view of the waveguide mixer taken along the line 2—2 of FIG. 1 and showing the crystal mixer at the intersection of the two crossed waveguides.

FIG. 3 is a perspective view of the crossed waveguides in a unitary form.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1 and 2 disclose the detailed structure of the novel crossed waveguide microwave mixer, generally designated 10. While other applications of the mixer are possible, the present invention is described in an embodiment suitable for use in laser spectroscopy. In this respect, the term laser is used in reference to any high-frequency electromagnetic source.

The mixer 10 has a structural housing 12 which supports the individual operating components. The housing 12 is an elongated, conductive member having a hollow central section 14. The housing may be either square or circular in cross section. At the lower portion of the housing 12 and within the hollow central portion 14 are a pair of crossed waveguides 16 and 18. While the waveguides 16 and 18 are referred to separately, the two waveguides may in actuality be a single, metallic cruciform element, as shown in FIG. 3, constructed by an electroforming process using precision mandrels. The material from which the waveguide is formed may be a conductor, such as brass, and the internal surfaces of the waveguides may be polished and plated with a high-work function material such as gold.

In FIG. 2 waveguide 16 is shown cut away along a central cross section. Waveguide 18 crosses over waveguide 16 at its midpoint where the two waveguides share a thin common wall. The waveguides 16 and 18 are supported in the central portion 14 of the housing 12 on a platform 20 and are held in position by means of a clamping block 22. A suitable fastener or bonding agent may be applied between the block 22, the waveguide 12 and the housing 14 to hole the waveguides in place. A transfer aperture 24 is drilled through the cruciform structure forming the crossed waveguides 16 and 18 at the central crossing point of the waveguides and mating apertures 26 and 28 in the platform 20 in block 22 respectively form an open channel through which a crystal mixer, generally designated 30, extends. The crystal mixer is typical of those found in the prior art and consists, for example, of a silicon or germanium crystal 32 and a cat's whisker 34 made from a conductive tungsten wire having a point contact with the crystal. The crystal 32 is sometimes referred to as a diode due to its semiconductor properties even at microwave frequencies.

The crystal mixer 30 is supported in the transfer aperture 24 through the crossed waveguides 16 and 18 so that the mixer 30 does not touch the waveguides 16 and 18. A differential screw assembly 36 having a movable grip 37 is mounted in the lower end of housing 12 with the grip 37 being translatable vertically toward and away from the waveguides 16 and 18 by means of a screw drive arrangement (not shown). The purpose of the differential screw assembly supporting the crystal diode 32 is to provide a very fine adjustment in the translational movement of the diode. The crystal 32 is supported on the upwardly projecting end of a conductive supporting block 40 locked within the grip 37 by means of a set screw 42. The one side of the crystal 32 is electrically connected through the screw assembly 36 to the waveguides and housing 12. The whisker 34 extends through each of the waveguides and is connected to the lower end of a conductive post 44 which is held by a force fit in the insulator 38 in the upper portion of housing 12. The whisker acts as an antenna to abstract electromagnetic energy from the waveguides and transfer the energy to the crystal 32 for further processing.

At the upper end of housing **12** as seen in FIG. **2**, a coaxial connector **39** such as a low-frequency-type "BNC" or "N" connector is mounted with a coaxial conductor **41** leading to insulator **38**. Within the insulator **38**, the conductor **41** is force fitted with conductive post **44** which supports the whisker **34**. The connector **39** is used to derive the low-frequency output when the waveguide mixer **10** is used with a local oscillator as a superheterodyne mixer.

A pair of pyramidal signal input horns **50** and **52** are disposed at opposite ends of the waveguide **16**. At the inward ends of the horns **50** and **52**, neck portions **54** and **56** are received respectively in mating rectangular apertures **58** and **60** of the housing **12**. The horns **50** and **52** and neck portions **54** and **56** are permitted to displace in a generally axial direction with respect to the ends of the waveguide **16** by means of a pair of leaf springs **62** and **64** to which the horns **50** and **52**, respectively, are soldered. The leaf springs **62** and **64** are fastened to the housing **12** at their lower ends by means of bolts **66** and **68**. The leaf springs **62** and **64** contain flex hinges **70** and **72**, respectively, in the vicinity of the mounting bolts. At the opposite or upper end of the springs as viewed in FIG. **2**, the leaf springs **62** and **64** contain apertures through which tuning screws **74** and **76** project respectively from housing **12**. Interposed between the leaf springs and the tuning screws are plastic bushings **78** or **80**. From this construction, it is readily apparent that the input horns **50** and **52** can be displaced generally in the axial direction with respect to the ends of waveguide **16** through the adjustment of the tuning screws **74** and **76**. This adjustment varies the size of a gap or tuning cavity formed between the confronting faces of the horns and end surfaces of waveguide **16** incrementally from 0, at abutment of the horns with the end surfaces, to a few thousandths of an inch. Such tuning cavities can be employed to transmit microwave energy between the movable waveguides with maximum efficiency.

It will be immediately recognized that the tuning screws are individually adjustable. As a consequence, electromagnetic radiation introduced through horn **50** may be of a different frequency than that introduced through horn **52**, and both inputs can be tuned to the mixer for maximum efficiency. In the prior art devices, tuning could be accomplished by adjusting a slug in the end of the waveguide opposite the signal input horn. However, in the prior art devices, the necessity for installing a tuning plug in one end of the waveguide eliminated that end as a receiving port for a second input signal. It will therefore be understood that one advantage of the present construction is that two signal inputs can be transmitted to ports at opposite ends of the same waveguide and each of the input signals may be individually adjusted for maximum signal transfer.

When the incoming signals in waveguide **16** are combined and transmitted through mixer **30** to the whisker **34**, it is possible to add a third input signal through flange **90** seen in FIG. **1**, connected to one port on an extended end of waveguide **18**. A conventional, adjustable shorting stub **92** is mounted to the opposite side of housing **12** from flange **90** and projects within the end of waveguide **18** for tuning the input signal introduced at flange **90**. In a typical superheterodyne receiver, the flange **90** on waveguide **18** is connected to a local oscillator and the combined output of the three mixed signals is removed through the low-frequency connector **39**.

While the novel crossed waveguide device has been described in one particular embodiment, it is to be understood that various modifications and substitutions can be made without departing from the spirit of the invention. While the horns **50** and **52** have been shown mounted on leaf springs, it will be understood that axial translation of the input horns with respect to the waveguide ends can be acquired by equivalent adjusting mechanisms. At the innermost position, the horns **50** and **52** should abut the ends of waveguide **16** and adjustment of the horn by a few thousandths of an inch permits tuning over a wide spectrum of input frequencies. It will therefore be understood that the present invention has been described by way of illustration rather than limitation.

What is claimed is:

1. A crossed waveguide device comprising:
a first waveguide having first and second ends;
a second waveguide crossed over and contacting the first waveguide and having an interconnecting transfer aperture extending transversely through the contacting walls of the waveguides at the crossing;
a first signal horn aligned with first end of the first waveguide; and
first means connected between the first input horn and the first waveguide for translating the input horn toward and away from the first end.

2. The waveguide device of claim **1** including:
a second signal input horn aligned with the second end of the first waveguide; and
second means connected between the second input horn and the first waveguide for translating the second input horn toward and away from the second end.

3. The crossed waveguide device of claim **1** wherein:
the first and second waveguides include apertures in the walls opposite the contacting walls, the apertures being aligned with the interconnecting transfer aperture whereby a through passageway is formed at the crossing of the first and second waveguides; and
a crystal mixer composed of a crystal and conductive whisker are mounted in the through passageway in non-contacting relationship with the waveguides.

4. The crossed waveguide device of claim **3** wherein:
one side of the crystal is electrically connected to the waveguides and the whisker contacts the opposite side of the crystal and extends in the passageway through both of the waveguides in electrically insulated relationship with the waveguides.

5. The crossed waveguide device of claim **1** wherein:
a housing is provided for the crossed waveguides, the crossed waveguides being mounted within the housing;
the first signal horn, the housing, and the first end of the first waveguide define a tuning cavity between the horn and the waveguide; and
the first means is an adjusting means connected between the first input horn and the housing for adjusting the size of the tuning cavity.

6. The crossed waveguide device of claim **5** wherein:
the adjusting means includes a flexible leaf spring connected to the housing at one portion of the spring and an adjusting screw extending between another portion of the leaf spring and the housing for adjusting the position of the spring with respect to the housing; and
the first signal input horn is supported adjacent the first end of the first waveguide by the leaf spring.

7. The crossed waveguide device of claim **6** wherein:
the leaf spring of the adjusting means has a first adjusting position in which the first signal input horn is supported in abutting relationship with the first end of the first waveguide.

8. The crossed waveguide device of claim **7** wherein:
the leaf spring of the adjusting means has a second adjusting position in which the first signal input horn is displaced incrementally away from the first end of the first waveguide.

9. The crossed waveguide device of claim **2** wherein:
a housing is provided for the crossed waveguides, the crossed waveguides being mounted within the housing;
the housing and the first and second signal horns define tuning cavities at the respective ends of the first waveguide;
the first means is first adjusting means connected between the housing and the first signal horn for adjusting the tuning cavity at the first end of the first waveguide; and
the second means is a second adjusting means connected between the housing and the second signal horn for adjusting the tuning cavity at the second end of the first waveguide independently of the cavity at the first end.

10. The crossed waveguide device of claim **9** wherein:
the first adjusting means has an adjustable screw connection with the housing for incrementally adjusting the tuning

cavity between the first horn and the first end of the first waveguide; and

the second adjusting means also has an adjustable screw connection with the housing for incrementally adjusting the tuning cavity between the second horn and the second end of the first waveguide.

11. The crossed waveguide device of claim **9** wherein:

a flange connection is joined to the second waveguide at one end; and

an adjustable shorting stub is mounted in the second waveguide at the other end.

12. The crossed waveguide device of claim **9** wherein:

the first and second crossed waveguides are formed by a single metallic cruciform element.

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