NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

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REPLY TO
ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for
Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3434037

Government or
Corporate Employee : TRW Inc.
TRW Systems Group
Redondo Beach
Calif. 90278

Supplementary Corporate
Source (if applicable) : n/a

NASA Patent Case No. : XMF-04958-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes ☑ No ☐
Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

Dorothy J. Jackson
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Enclosure
Copy of Patent cited above

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March 18, 1969 J. H. HABRA 3,434,037

MULTIPLE VARACTOR FREQUENCY DOUBLER

Filed April 15, 1965

N71-26414
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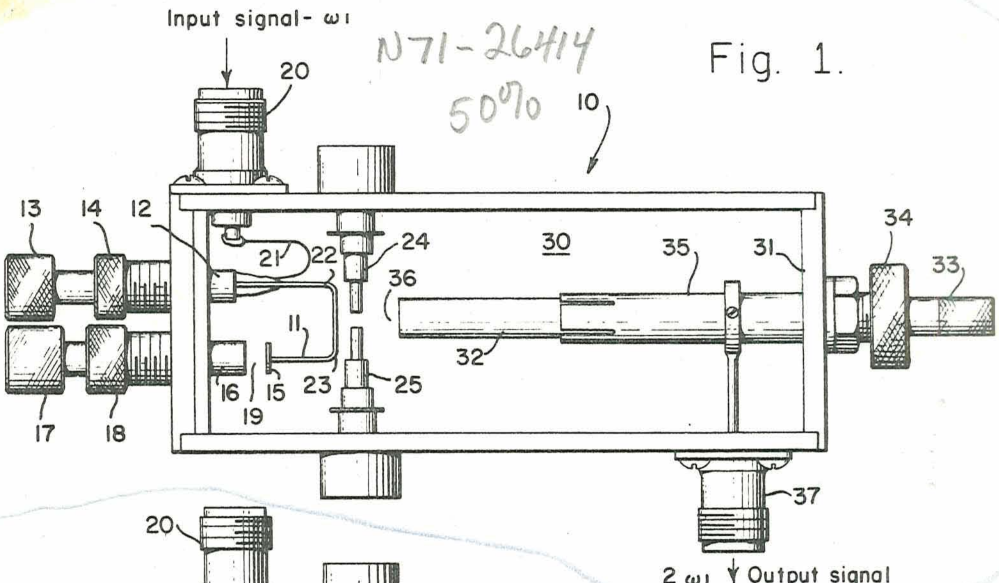

Fig. 1.

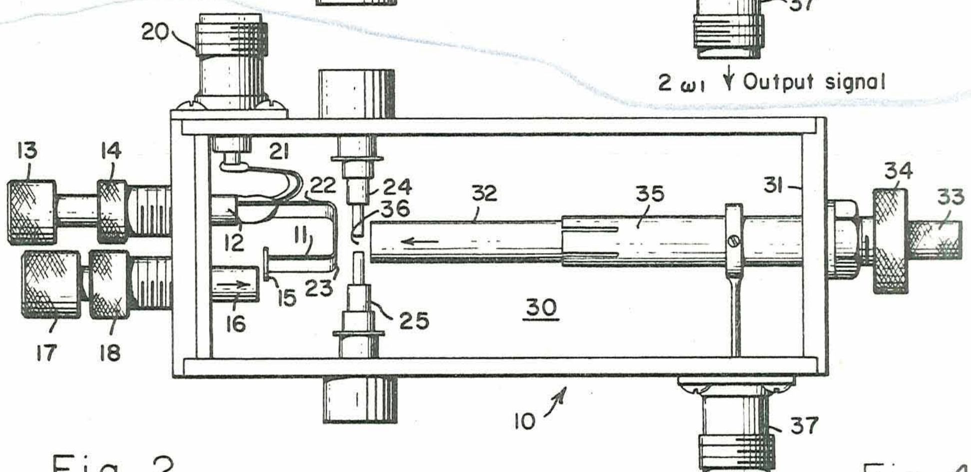

Fig. 2.

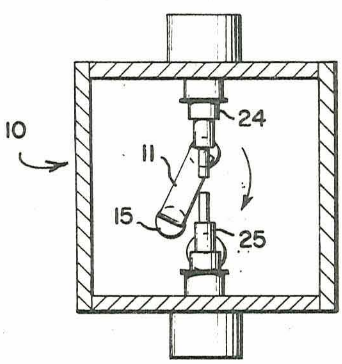

Fig. 3.

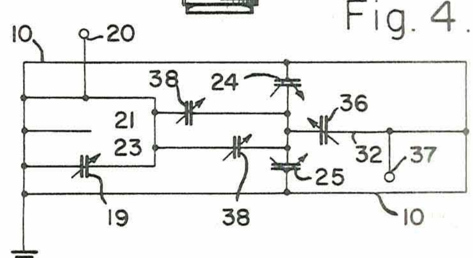

Fig. 4.

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United States Patent Office

3,434,037
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3,434,037

MULTIPLE VARACTOR FREQUENCY DOUBLER

Joseph H. Habra, Lawndale, Calif., may be granted to National Aeronautics and Space Administration under provisions of 42 U.S.C. 2457(d)

Filed Apr. 15, 1965, Ser. No. 448,365

U.S. Cl. 321—69 **1 Claim**

Int. Cl. H02m *5/16;* **H01p** *7/00*

ABSTRACT OF THE DISCLOSURE

A frequency multiplier comprising a dual cavity device in which the input cavity resonates at a frequency of ω_1 and an output cavity arranged to resonate at a frequency of $2\omega_1$. A pair of varactor elements external to the input cavity is coupled to said input cavity for generating current of the desired output frequency. The output cavity includes the dual varactors as part of the tuned circuit for generating the desired multiplied frequency.

This invention relates to the art of frequency multiplication from a low frequency source to frequencies in the microwave region and more particularly, to a varactor multiplier using two or more varactors for generating high frequencies having higher power and efficiency than previously obtained with common frequency multipliers.

The potential applications for solid-state R-F transmitters in Communication and Radar continue to increase particularly in connection with Electronic Space Systems. Coincidental with the increasing number of applications are the more stringent requirements of solid-state transmitters (power sources) with regard to increased power generation, increased reliability and increased operating stability.

In this invention, two or more nonlinear voltage variable capacitor commonly called varactors, are used to generate high power at microwave frequencies and with high conversion efficiency.

The advantages of the multiple varactor frequency doubler are, first, lower power dissipation in each varactor diode which permits the frequency doubler to handle n times the power of a single varactor frequency multiplier. Second, for a given power input the varactor dissipation is $1/n$ times the dissipation of a single varactor frequency doubler. The deterioration of the varactor Q is less and the doubler efficiency is higher than for the one varactor type frequency doubler.

The invention is preferably implemented by means of two resonant circuits. The input circuit is tuned to ω_1 and coupled to an output circuit which includes two or more varactors that are excited by an input signal having a frequency of ω_1 equal to the resonant frequency of the defined input circuit. The output frequency of $2\omega_1$ is obtained by coupling the ω_1 signal from the input resonant circuit to the output resonant circuit through the varactors.

A multiple varactor frequency doubler has been constructed in the S and C bands by using two varactors. The output frequency $2\omega_1$ is obtained from an output circuit that resonates at $2\omega_1$. The defined dual varactor frequency doubler is implemented by including the two varactors in the output resonant circuit which is coupled to the desired input frequency of ω_1.

The new doubler is achieved by matching two dissimilar varactors at different impedance points on the input resonator. The coupling or matching of the input resonator to the two varactors is accomplished capacitively. Two currents of the input frequency ω_1 will flow in each of the two varactors. The output currents at $2\omega_1$ are obtained by means of symmetrically locating the two

varactors with respect to the inductive output line. The output resonator is tuned to $2\omega_1$.

Further objectives and advantages of the present invention will be made more apparent by referring now to the accompanying drawings wherein:

FIGURE I is a pictorial representation of the actual construction using two varactors in a frequency multiplier according to the teachings of this invention;

FIGURE II is a modification of FIGURE I more fully illustrating the techniques used to accomplish the tuning of the input circuit to the individual varactors and the symmetrical coupling between the varactors and the output circuit;

FIGURE III is an end view of the input circuit illustrated in FIGURE II, more fully illustrating the mechanical tuning of the input circuit to the varactors; and

FIGURE IV is a schematic diagram of the mechanical circuits illustrated in FIGURES I and II.

Referring now to FIGURE I, there is shown a preferred embodiment of this invention, using a pair of varactors in a frequency multiplier capable of operating in the S or C band (1,000 mc. to 5,000 gc.). The entire device is contained within a shielded container **10**. At one end of the container **10** is an input line **11** connected to a plunger **12** at the low impedance end of the line and which is movable by means of knob **13** that is capable of being locked in a position by lock nut **14**. The high impedance end of the input line **11** is terminated at a shoulder **15** which is formed to oppose a plunger **16** capable of being moved in an axial direction by means of knob **17** and that may be locked in position by lock nut **18**. The gap between shoulder **15** and plunger **16** defines capacitor **19** that is varied by means of knob **17** in order to tune the input line **11** to the desired input frequency. An input signal ω_1 is fed from a suitable source, not illustrated, through an input terminal **20** to the input line **11** through a flexible connection **21** that is connected to the input line **11** at a point determined by the impedance of the line and the impedance of the input source.

In the preferred embodiment, the input line **11** has a substantially rectangular cross-section and is shaped in the form of a U having bends at points **22** and **23**. A plurality of varactors **24** and **25** are mounted to the container **10** and arranged to project along portions of the input line **11** between the bends **22** and **23**. Since the varactors **24** and **25** are coupled to different portions of the input line **11**, it is not necessary for the varactors to be identical but only that each varactor be properly matched to the input line **11**. The techniques employed to match the varactor to the input line are more fully illustrated in connection with FIGURE II.

The output cavity **30** located within the container **10** is defined by the cavity distance between the varactors **24** and **25** and the end **31** of the container **10** that is opposite the input line **11**. Tuning of the output cavity **30** is accomplished by means of a plunger **32** capable of being moved in an axial direction by means of a knob **33** and that may be locked in position by a lock nut **34**. The output cavity **30** is tuned by moving plunger **32** to close proximity with varactors **24** and **25**. According to the feature of this invention, it is necessary that the plurality of varactors be arranged symmetrically with respect to plunger **32**. In this embodiment, symmetry is assured by physically locating the varactors **24** and **25** on opposite sides of container **10** and locking plunger **32** in the center line of the container to insure equal coupling to both varactors. For those multipliers using more than two varactors, it would be necessary to symmetrically locate the varactors radially from the center with respect to the output tuning plunger **32**. The capacity between the output tuning plunger **32** and the varactors **24** and **25** is the output tuning capacitor **36** used to tune the output capacitor to the output frequency of $2\omega_1$. The output signal of $2\omega_1$ is obtained from a fixed position **35** of the tuning plunger and depending on the impedance conditions, the output signal is fed through an output terminal **37** to a suitable utilizing device not illustrated.

Referring now to FIGURE II, there is shown a drawing similar to that illustrated in FIGURE I but more fully illustrating how the input line **11** is coupled to each of the varactors **24** and **25**. As mentioned previously in connection with FIGURE I, rotating the knob **13** will cause the input line **11** to swing in an arc as illustrated in FIGURE III. The significance of this is the fact that different positions of the input line **11** facing the varactors **24** and **25** may be selected in an effort to individually match the impedance of the different positions of the input line to the individual varactors. Coupled with this movement, it is also possible to move knob **13** in an axial direction to thereby vary the coupling between input line **11** and the varactors **24** and **25**. Since the input line **11** is capable of being translationally and rotationally moved, it is now apparent why the input signal is connected via a flexible line **21**. Tuning of the input line **11** to a frequency of ω_1 is still accomplished by rotating knob **17** which has the effect of moving plunger **16** in an axial direction. The symmetrical coupling between the varactors and the output circuit is assured by the physical location of plunger **32** with respect to the varactors used as mentioned in connection with FIGURE I.

Referring now to FIGURE IV, there is shown a schematic diagram of the dual varactor multiplier illustrated in connection with FIGURES I, II, and III. The defined input resonant circuit consists of the tuned input line **11**, which includes capacitor **19** and the two varactors **24** and **25**, together with the coupling capacitors **38** existing between individual positions of the input line **11** and varactors **24** and **25** respectively. The input series resonant circuit is excited by the input signal of ω_1. The output frequency of $2\omega_1$ is obtained by means of an output series resonant circuit consisting of the output cavity **30** which includes capacitors **36** and varactors **24** and **25**.

This completes the description of the embodiment of the invention illustrated herein. However, many modifications and advantages thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. Accordingly, it is desired that this invention not be limited to the particular details of the embodiment disclosed herein, except as defined by the appended claim.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A frequency multiplier comprising

a folded input resonant line tuned to a resonate frequency of ω_1 by a capacitor at one end, said input line having a substantially rectangular cross-section means for moving said input resonant line; and

an output resonant cavity having at least two varactors symmetrically coupled to said input cavity;

each of said varactors coupled to different parts of said rectangular input line.

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U.S. Cl. X.R.

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