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(54) KU-BAND MINIATURE WAVEGUIDE LOW PASS FILTER

KU-BAND-MINIATUR-WELLENLEITER-TIEFPASSFILTER

FILTRE PASSE-BAS À GUIDE D'ONDE MINIATURE EN BANDE KU

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Description

The Related Art

[0001] This invention relates to a new method for Waveguide Low Pass Filters suppressing harmonics and higher order waveguide modes (to prevent interaction with other satellites) occurring in OMUX -Output Multiplexer channels in satellites.

Background of the Invention

[0002] A typical module used in Waveguide Low Pass (LP) filter structures is shown in three dimensional in Figure 1a. Ku-band LP filters are designed and produced by successively adding such modules. The module shown in said figure consists of two cavity(C) resonators and waveguide (WG) part interconnecting such cavities (C). Length of waveguides is shown with "d", width (wide edge) with "a", height (narrow edge) with "b", cavity length with "s" and heights with "h". Generally width of cavity (C) is taken same as wave guide width (a). Figure 1b shows side cross-section of same dimensions. Figure 1c shows side cross-section of a typical Waveguide LP filter structure.

[0003] Wide edge (a) of waveguide parts determines electromagnetic waves modes propagating in such embodiments. Basic Mode is taken as TE10. For propagation of this Mode, wave frequency (f) should be higher than cutoff frequency (fc10) of this Mode. When the frequency gets higher, in addition to TE10 Mode, undesired TE01, TE20, TE30, E40... and similar Modes are also produced, and energy is distributed and spread to such modes and deformation in signal occurs. LP filter is expected to stop such Modes. In other words, filter is expected to propagate only TE10 Mode. In addition, even only TE10 Mode is propagated, the power amplifiers in the system may generate harmonics (nfo) of basic frequency (fo) and such harmonics may be generated by TE10 Mode. LP filter is also expected to suppress such harmonics. Stopband covers very wide frequency range for Ku Band filters such as 14 - 40 GHz (for 3rd harmonic suppression). The suppression level required at this band is of so high levels such as 60 - 80 dB (decibel) according to application. On the other hand, filter input is expected to show a return loss of 20 - 30 dB in system in the targeted passband (PB).

[0004] Such filters can be designed by means of two competing approaches, namely:

- by use of "Filter Synthesis software" using Circuit Theory,
- EM optimization approach using Electromagnetic Field (EM) theory.

[0005] Advantages of filter synthesis approaches is that specifications such as Pass-Band-PB, Stop-Band-SB and PB-SB transition band tendency and filter degree are under control of designer. Degree restrictions arising from old synthesis softwares and experiencing difficulties in production of component values obtained as a result of synthesis by available technologies in some cases were disadvantages of the synthesis approach.

[0006] These disadvantages of the old synthesis approaches have caused development of EM Optimization techniques. With these techniques, realizable component member values and sizes are selected to start the design using directly EM optimization methods. Optimization is continued until targeted specifications are provided. The disadvantages of this approach are uncertainty whether or not designed filter is optimum in all aspects and the probability of ignoring advantages of synthesis approach by leaving control of filter parameters to optimization software entirely.

[0007] Literature has multiple numbers of publications about various embodiments capable to provide such specifications. Some of papers with biggest claims and presenting the most modern approaches and published in recent years are explained below.

[0008] In the paper described under Reference [1], main filter (rejection filter) is synthesized as series combinations of alternating Unit Element (UE- transmission line) and series stubs (ST) by using of distributed parameter circuit theory. ST's are used to create transmission zeros (TZ's) in the stopband to achieve high insertion loss (suppression) and steep transition (high selectivity) from passband (PB) to stopband (SB). UE's are used both to physically separate ST's and also to shape the response of the filter. Then UE's are transformed into rectangular waveguides (RectWG) and ST's are transformed into cavities (rectangular waveguide stubs (RectWGST)). Impedance matching circuits are added to inputs and outputs of this circuit and the final structure is formed (Figure 2). Because of numerical error restrictions in old synthesis softwares, degree of the filter (element numbers) remain at low levels and therefore fail to meet too wide band stop specifications of todays applications. Furthermore, discontinuities of step type and failure to control heights of waveguide parts (b) may cause multipaction problems in high power applications. The new design method disclosed under this patent takes the filter specification of said papers.

[0009] New LP filter embodiments developed by this method provide same or better of specifications given in reference papers. The method is much simpler and easier when compared to methods used in references. Productions of obtained embodiments are possible by standard technologies.

[0010] In the paper referred to in reference [2], sinusoidal profile cavities shown in Figure 3 are used instead of stubs in order to eliminate the power restriction issue caused by discontinuities in ST-UE steps of Reference [1]. With this embodiment both high power levels are achieved and 60 dB rejection between 13.75 - 40 GHz has been provided. However, total length could not fall below 21.8 cm (centimeters). This embodiment also consists of three blocks, input-output matching circuits and main filter part.

[0011] In Reference [3], LP filter is designed through EM Optimization approach entirely. The embodiment is shown in Figure 4. In this approach, first E-M models of cavity and waveguides are derived in broad frequency range. Transmission Zeros (TZ's) created by cavities are determined in EM medium by use of Y-parameters through employment of such models. Insertion loss of the filter in its stopband (SB suppression) is shaped by successive connection of cavities and waveguides. Number of modules is selected subject to suppression amount and suppression band width. E-M optimization is started by selecting sizes of both waveguide parts and cavities. Sizes are selected in a manner not causing power restriction issue.

[0012] The embodiment shown in Figure 4 consists also of three separately designed parts. Two parts on the left are two filters with differently selected sizes "a". The third part is impedance matching circuit. The first filter on the left provides suppressing harmonics in TE10 Mode while the second filter provides rejection undesired Modes such as TE01, TE20, TE30, TE40.

[0013] Optimization specifies both waveguide heights and cavity heights. Satisfactory results are obtained for both high power and stop of 14 - 40 GHz band. Total size is of 15 cm level.

[0014] In the paper given in Reference [4], the filter consists of three parts (input and output impedance matchings and main rejection filter) as shown in Figure 5. This embodiment consists also of both input and output matching circuits and the main filter formed by cavities separated by waveguide pieces. Design parameters are taken as cavity heights (h) and cavity lengths (s), waveguide heights (b) and waveguide lengths (d). Design is completely made by E-M Optimization. In optimization waveguide lengths (d) and cavity lengths (s) are kept very small and constant and thus total size is provided to be short. Optimization variable parameters are only cavity heights (h) and waveguide heights (b). Waveguide height (b) is kept over a certain value taking power restriction into account.

[0015] Stopband suppression higher than 60 dB over 13.5-40 GHz range is provided by spreading the Z's into stopband properly while selectivity of filter in the transition band from PB to SB is provided by placing more TZ's close to PB edge. Pass band Return Loss is higher than 20 dB. Total filter size is reduced to considerably small value such as 8.5 cm when compared to other approaches. This filter is designed to provide rejection at TE10 Mode only. Other TEn0 Modes can be suppressed by adjusting waveguides width (a).

[0016] Reference [5] describes classical RectWG filters made up of non-ridged or ridged RectWG resonators coupled by irises or posts using known circuit transformations. There is no UE-STUB type filter circuits in this reference.

[0017] In Reference [6], a filter design realized with an electromagnetic (EM) optimization approach is disclosed. In the approach, EM models are produced in the wide frequency bands of the cavity and wave guides. The transmission zeros (TZ) created by the cavities by means of using EM models are determined within EM environment by means of using Y-parameters of the equivalent circuits. The suppression band of the LP filter is formed by spreading the TZ's within the stop band of the LP filter. The number of the modules is selected depending on the suppression amount and suppression band width. EM optimization is started by means of selecting estimated values for both the wave guide parts and the cavity sizes. The sizes are selected in a manner such that they do not lead to power limiting (multipaction) problem.

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Problems Solved by the Invention

[0019] The invention has been defined in the independent claim. Further specific technical features have been defined in the dependent claim.

[0020] This invention relates to a computer aided design method for design of harmonic and high order mode signal in output multiplexer channels suppressing Low

Pass Filters by waveguide technique in satellites. The example circuit given in the invention is given as a sample application for a miniature Low Pass Filter suppressing at least 60 dB in the SB from 13.5 GHz up to 40 GHz with a PB from fp1=11600 MHz to fp2=12700 MHz with 34 dB return loss. Size of the filter is 6.9 cm, smaller than all the other filters described in references.

[0021] In the new approach developed it is started with new filter synthesis software capable to synthesize very high order filters. All capabilities and advantages of synthesis approach are used to the full level. EM Optimization is used only for fine adjustments after reaching to close to targeted structure and specifications. Thus advantages of both approaches are used to the fullest level.

[0022] Another characteristic distinguishing this method from approaches given in the above references can be summarized as follows: In the approaches given in the references, filters are taken as three parts (rejection filter, input impedance matching circuit and output matching circuit) and these parts are optimized separately and then brought together and optimized again. Very high order and very small size filers are designed as single part by use of the synthesis method developed under this invention. In other words, with the new approach developed under the invention, the entire filter, that is both matching and suppressing circuits can be synthesized as one single part. Thus all of circuit elements contribute to both PB impedance matching and SB suppression. This helps shortening filter size, enhancement of selectivity and increasing rejection level. In addition, both power, cavity sizes and waveguide length and height can be taken under control by means of developed circuit transformations. This eliminates power multipaction issues.

[0023] With the new approach, it is aimed to achieve the performance of structure in Reference [4] seeming as the most successful one in the literature. Instead of synthesis technique used in Reference [1] and being inadequate, a new filter synthesizing method capable to synthesize much higher order and much shorter size filters has been developed. It has been shown that with this approach, shorter filter can be designed with better specifications compared to those in references in an easier way with more controlled parameters.

[0024] In brief, by use of computer aided design method disclosed under the invention:

- Almost all of design is made by exact synthesis at circuit theory level but at final stage EM Optimization should be used for fine tuning.
- Size of filter can be reduced to much smaller sizes.
- Because all parameters of all elements contribute to matching, Return Loss in PB can be raised to much higher levels in comparison with other approaches.
- Power multipaction problem is avoided by proper selection of WG and cavity dimensions right from the beginning of the synthesis stage.
- Rejection at 13.5-40 GHz band is at same level as other approaches (>60 dB) and higher rejection can be achieved if required.
- Selectivity can be adjusted as desired by properly locating more TZ's closer to the PB.

Detailed Description of the Invention

[0025] The invention is a computer aided design method as described in the figures below:

Figure 1.

a) A perspective view of a typical module used in waveguide Low Pass filter embodiment

b) Side cross-section view of the module in Figure 1a.

c) Side cross-section view of a typical Waveguide Low Pass filter embodiment.

Figure 2. Side cross-section view of circuit in Reference [1].

Figure 3. Side cross-section view of circuit having sinusoidal profile cavities mentioned in Reference [2].

Figure 4.

a) A side cross-section view of three-part circuit mentioned in reference [3]
b) top cross-section view of the circuit in Figure 4a.

Figure 5. A side cross-section view of three-part circuit mentioned in reference [4]

Figure 6. a) - e) design steps of method disclosed under invention
f) front cross-section view of synthesized low pass circuit.

[0026] The parts indicated in the figures have been designated separate numbers and said numbers are given below:

a. Waveguide width

b. Waveguide height

d. Waveguide length

C. Cavity

h. Cavity height/ stub length

s. Cavity length/ stub width

ST. Stub

UE. Transmission line

I. Inverter

R_S. Source resistance

R_L. Load resistance

RectWG. Rectangular Waveguide

FTZ. Finite transmission zero

Z. Impedance value

PB. Pass band

[0027] In the most basic form, a computer aided design method for designing a Ku-Band Miniature Waveguide Low Pass Filter suppressing harmonic and higher order mode signals generated at output multiplexer in satellites. Design steps are described in an illustrative application of the invention shown in Figure 6. The targeted pass band (PB) frequency range is determined as f_{p1}=11600 MHz, f_{p2}=12700 MHz with return loss greater than 30 dB. Stopband (SB) is determined as fs1=13500 MHz, fs2=40000 MHz with insertion loss (rejection) greater than 60 dB. The approach consists of steps of;

- Selection of filter parameters via graphical interface of filter synthesis program by use of data input interface,
- Synthesizing a distributed parameter low pass circuit consisting of transmission lines (UE) interconnected in series with short circuit stubs (ST's) in an alternating manner between a source resistance (Rs) and a load resistance (RL) as shown in Figure-6.a,
- Raising circuit impedance level by locating an inverter (I) on each end of formed circuit in such a manner as the impedances of UE's and ST's will be compatible for realization using WR75 type Ku-band RectWG (Figure 6.b),
- Conversion of transmission lines (UE) in circuit to equivalent reduced height WR75 RectWG's (Figure 6.c),
- Conversion of stubs (ST) of the circuit into equivalent WR75 type RectWG Stubs (cavities, C) with desired trial lengths to settle the locations of TZ's (Figure 6.d),
- Brute force replacement of Rs-Inverter and Inverter-RL pairs at circuit ends by the WR75 type RectWG pieces which are simulated by their characteristic impedance at the upper PB edge of fp2=12700 MHz. This brute force replacement of circuit terminations degrades Return Loss in the passband and suppression in stopband which will be recovered by adjustment of RectWG and RectWG Stub parameters as described in the succeeding stages,
- Adjustment of stub lengths (h) in a manner to create transmission zero at more than one frequency in stop band,
- Adjustment of stub lengths (h) and waveguide heights (b) and thus adjustment of return loss in pass band and selectivity of filter,
- Display of synthesized filter on screen.

[0028] The invention is a computer aided design method for designing Ku-Band Miniature Waveguide Low Pass Filter and this method can be performed by means of an electric device (for instance a desktop computer, laptop computer, tablet computer .... etc.) consisting of a data input interface (a keyboard, mouse, touch screen...) for receiving design parameters from user, a memory unit storing a filter synthesizing software having a graphical user interface (a hard disk, flash disk, external hard disk), an adapted processor unit for running said filter synthesizing software, and a screen for graphical display of designed circuit and simulation.

[0029] Said filter synthesizing software has a graphical user interface and via this interface, selection of members of filters to be synthesized (transmission line (UE), stub (ST), inverter (I)...), fixing specifications of these members and filters or change thereof later (for instance, adjustment of cavity length (s), cavity height/stub lengths (h), waveguide width (a), waveguide height (b) and waveguide length (d), adjustment of pass/stop bands frequencies...), conversion of filter circuit into waveguide (RectWG) structure and return loss of synthesized circuit and simulation of reflection loss.

[0030] In this new approach, a Band Pass filter design is started in the form of a Distributed Parameter Low Pass filter. Transmission lines (UE) in circuit and short circuit stubs (ST) are converted into equivalent impedance waveguides (RectWG) (Ref-[1]). Because of High Pass features of Waveguides, circuit acts like a Band Pass filter. In literature such circuits are referred to as Waveguide Low Pass Filter (Ref [1]-[4]).

[0031] Steps for a Ku-Band Miniature Waveguide Low Pass Filter design realized by computer aided design method disclosed under the invention are indicated on an illustrative filter shown in Figures 6a-6e. The low pass filter consisting of transmission line (UE) and short circuit stubs (ST) is shown in Figure 6a, circuit scaled by use of inverters (I) according to waveguide (RectWG) cross section sizes selected in Figure 6b, adjustment of short circuit stubs length (h) in a manner to distribute finite transmission zeros (FTZ) in stop band in Figure 6c, conversion of transmission lines (UE) into equivalent waveguides (RectWG) and stubs (ST) into RectWG cavities, thus forming initial circuit in figure 6d, replacement of source/load impedances and inverters by Ku-Band

RectWG pieces simulated by the impedance of the Ku-band WG evaluated at upper PB edge frequency fp2=12700 MHz, adjustment of waveguide heights (b) and stub lengths (h) and thus achievement of targeted insertion loss and return loss values in pass and stop bands (stopband loss > 60 dB and return loss > 34dB) in figure 6e.

[0032] In the first step of the method disclosed under the invention filter parameters are selected via graphical interface of filter synthesis program by use of said data input interface. In an illustrative application of the invention described in Figure 6, the targeted Band Pass filter pass band frequency range is determined as f_{p1}=11600 MHz, f_{p2}=12700 MHz. It is targeted to have return loss higher than 30 dB. Frequency range of stop band is set as f_{s1}=13500 MHz, f_{s2} = 40000 MHz. Specifications of the low pass filter are selected as follows: f_p=12700 MHz, f_q=94500 MHz. Here f_p is cutoff frequency of low pass filter which is also the upper edge of the targeted passband, f_{p2}. f_q is quarter wavelength frequency of low pass filter in transmission line (UE) - stub (ST) embodiment to be synthesized. When the UE is transformed into RectWG structure, the trial quarter wavelength frequency f_q=94500 MHz results in 1 mm length for the RectWg, leading to miniature overall size for the filter. Shorter values can also be selected as desired for further miniaturization.

[0033] Input and output of the filter will be ended with WR75 type waveguides (RectWG). Width (a) of said waveguides to be used at input and output of filter is 19.05 mm, height (b) waveguides is 9.525 mm. Width (a) of other waveguides inside filter are also 19.05 mm, the same as the width of the terminating waveguides while heights (b) of waveguides inside the filter are variable and minimum value is taken as 3 mm in order to prevent multipaction. Numbers of transmission line (UE) and stub (ST) forming low pass filter are selected as N_{ue}=18 and N_{stub}=17. Thus degree of filter is N= 17 + 18 = 35.

[0034] After determination of parameters to be used in design, the circuit elements are synthesized as series connected transmission line (UE) + stub (ST) + transmission line (UE) + stub (ST) + ..., as shown Figure 6a between a source resistance (Rs) and a load resistance (RL). Impedance values (Z) of circuit elements are shown under relevant circuit elements.

[0035] In the next step, one inverter (I) is placed each of both ends of circuit and circuit impedance level is increased such that the impedances of UE's and ST's will be compatible for conversion into RectWG pieces and RectWG Stubs respectively using Ku-band WR75 type waveguide pieces. In the illustrative application of the invention, one inverter (I) is placed on each of circuit ends in a manner that the UE in the very middle of the circuit will be equivalent to a reduced height WR75 type RectWG with width a=19.05 mm and reduced height of b=3 mm.

[0036] In the next step, the transmission lines (UE) in circuit are converted into equivalent RectWG's with reduced heights b in the range 3 mm-to-7.26 mm. Lengths of all WG's are 1 mm as set by the quarter wavelength frequency of f_q= 94500 MHz (Figure 6c).

[0037] Also short circuit stubs (ST) in this step are converted into equivalent cavities (C) (RectWG Stubs). During such conversions, WG Stub lengths (h) are adjusted in a manner to create Transmission Zeros-TZ's) at various frequencies to shape the stopband insertion loss response. In this example all WG Stub widths are kept at 6 mm. When stubs are realized in two parallel pieces in symmetric manner, one above and one below the longitudinal symmetry line, as shown in Figure 6.f, stub widths will be halved to 3 mm, thus reducing total length of the filter while also preventing multipaction. Distribution of TZ's within the stop band are manually adjusted to give stopband loss higher than 60 dB by means of a number of iterations over the band 13500 MHz-to-40000 MHz (Figure 6d). Selectivity of the filter is also adjusted by placing sufficient number of TZ's close to stopband edge of 13500 MHz.

[0038] Thus, the stopband of the filter is roughly shaped as shown in Figure 6.d. Stub lengths varies between 2.35 mm-to-6.47 mm

[0039] The targeted passband (PB) edge frequencies are fp1=11600 MHz and fp2=12700 MHz with higher than 30 dB return loss. Formation of the passband is carried out through the following steps:

Rs-Inverter and Inverter-RL pairs at source and load ends are replaced by WR75 waveguides of width a=19.05 mm and height b=9.525 mm. The terminating WR75 waveguides are simulated by their characteristic impedance at f_{p2} =12700 MHz which is calculated as 494.76 Ohms. So, in circuit simulations the new Rs and RL are set as 494.76 Ohms as shown in Figure 6.d. Selection of frequency as f_{p2} here is to prevent deformation of band pass filter on upper edge and facilitate further optimization works. The return loss plot shown in Figure 6.d shows a wide passband with low return loss level. The targeted passband with desired return loss level is also shown in the same figure as shaded region. The targeted return loss level in the passband is reached by adjusting the heights (b) of RectWG pieces. Also, fine adjustment of WG stub lengths (h) helps to further improve return loss.

[0040] Some figures are indicated in two lines under circuits shown in Figures 6c-6d. Stub length (h) is indicated in upper line under stubs (ST) while stub width (s) is given in lower line. Waveguide lengths (d=1 mm) is given in upper line under waveguides (RectWG) while waveguide height (b) is shown in lower line. Said WG heights (b) are adjusted to improve the PB return loss level in the range f_{p1}=11600 MHz, f_{p2}=12700 MHz to 34 dB while the WG Stub lengths (h) (cavity heights) are adjusted both to improve filter selectivity (transition band slope) and to set the stopband loss higher than 60 dB over the band from 13500 MHz to 40000 MHz, as shown in Figure 6e.

[0041] In final step, synthesized filter is shown on the screen. In the illustrative application of the invention, synthesized low pass filter geometry is shown in Figure 6f. Said low pass filter total length is 18 transmission lines (UE) x 1 mm + 17 stubs (ST) x 3 mm = 69 mm. This is shorter (8.5 cm) than total length of filter having the highest performance in the related art (that is, Reference [4]).

[0042] After this stage, real performance examination and fine adjustments (discontinuity effects) can be conducted by use of electromagnetic simulation programs. The designed circuit is produced by use of a production device (for instance CNC - Computer Numerical Control).

[0043] Finally, filter performances in Reference [4] is exceeded in all aspects by means of above described method:

◦ Shorter filter length (6.9 mm), thus, lower insertion loss is provided,

◦ Higher return loss (34 dB) is provided.

◦ Same high selectivity: 60 dB rejection at 13500 MHz is provided,

◦ Wide stop band is provided (higher than 60 dB at 13.5-40 GHz band)

◦ Faster, easier and controlled design can be achieved in circuit theory plane by means of the developed software,

◦ E-M optimization is applied for only for fine settings as result very close to optimum target is achieved,

◦ If selected waveguide length (a) causes higher order Modes (TE20, TE30, ...), wide edges (a) of some of guides in circuit can be adjusted to prevent them.

Claims

1. A computer aided design method, for designing a Ku-band miniature waveguide low pass filter, wherein the waveguide low pass filter acts like a band pass filter due to the high pass features of the waveguides of the waveguide low pass filter, suitable for suppressing harmonic and higher order mode signals generated in multiplexers in satellites by use of an electrical device consisting of a memory unit storing a filter synthesis software having a graphical user interface, a processor unit adapted for running said filter synthesis software, a data input interface for receiving design parameters from a user and a monitor for graphical display of designed filter circuit simulation, wherein the band pass filter design is started in form of a distributed parameter low pass filter comprising transmission lines (UE) and short circuit stubs (ST) subsequently converted into equivalent impedance waveguides (RectWG), the method consisting of;

   - Selection of the following filter parameters via the graphical interface of the filter synthesis software by use of the data input interface,

     ◦ frequency range of pass band of the band pass filter,
     ◦ frequency range of stop band,
     ◦ cutoff frequency of the waveguide low pass filter to be designed, quarter wave length frequency of the distributed parameter eflow pass filter to be synthesized,
     ◦ width (a) and height (b) of waveguides to be used in the waveguide low pass filter,
     ◦ number of transmission lines (UE) and short circuit stubs (ST) to be used in the distributed parameter low pass filter,

   - Forming a distributed parameter low pass filter circuit consisting of transmission lines (UE) interconnected in series with short circuit stubs (ST), between a source resistance (Rs) and a load resistance (RL),
   - Raising circuit impedance level by locating an inverter (I) on each end of formed circuit,
   - Conversion of the transmission lines (UE) to equivalent waveguides (RectWG),
   - exchange of impedances at circuit ends with impedances of waveguides (RectWG) used at the input and output of the waveguide low pass filter at the cutoff frequency of the waveguide low pass filter,
   - Conversion of the short circuit efstubs (ST) into equivalent cavities (C),
   - Adjustment of stub lengths (h) in a manner to create transmission zeros at more than one frequency in stop band,
   - Adjustment of stub lengths (h) and waveguide heights (b) and thus adjustment of return loss in pass band and filter selectivity,
   - Display of synthesized filter on screen.

2. A computer aided design method according to claim 1 and it is **characterized in that** the product is produced by use of a production device after step of "Display of synthesized waveguide low pass filter on screen".

Patentansprüche

1. Computergestütztes Konstruktionsverfahren zum Konstruieren eines Bandminiatur-Wellenleitertiefpassfilters, wobei der Wellenleitertiefpassfilter aufgrund der Hochpassmerkmale der Wellenleiter des Wellenleitertiefpassfilters wie ein Bandpassfilter wirkt, das zum Unterdrücken von harmonischen Si-

gnalen und Modensignalen höherer Ordnung geeignet ist, die in Multiplexern in Satelliten erzeugt werden, durch Verwenden einer elektrischen Vorrichtung, die aus einer Speichereinheit besteht, die eine Filtersynthese-Software speichert, die eine grafische Benutzeroberfläche, eine Prozessoreinheit, die angepasst ist, um die Filtersynthese-Software auszuführen, eine Dateneingabeschnittstelle zum Empfangen von Konstruktionsparametern von einem Benutzer und einen Bildschirm zum grafischen Anzeigen einer Simulation von konstruierter Filterschaltung aufweist,
wobei die Bandpassfilterkonstruktion in Form eines Tiefpassfilters verteilter Parameter begonnen wird, umfassend Übertragungsleitungen (UE) und Kurzschluss-Stichleitungen (ST), die anschließend in äquivalente Impedanzwellenleiter (RectWG) umgewandelt werden, wobei das Verfahren aus Folgendem besteht:

- Auswahl der folgenden Filterparameter über die grafische Oberfläche der Filtersynthese-Software unter Verwendung der Dateneingabe-Schnittstelle,
    - ◦ Frequenzbereich des Durchlassbereichs des Bandpassfilters,
    - ◦ Frequenzbereich des Stoppbands,
    - ◦ Trennfrequenz des zu konstruierenden Wellenleitertiefpassfilters, Viertelwellenlängenfrequenz des zu synthetisierenden Tiefpassfilters verteilter Parameter,
    - ◦ Breite (a) und Höhe (b) von Wellenleitern, die in dem Wellenleitertiefpassfilter zu verwenden sind,
    - ◦ Anzahl von Übertragungsleitungen (UE) und Kurzschluss-Stichleitungen (ST), die in dem Tiefpassfilter verteilter Parameter verwendet werden sollen,
- Bilden einer Tiefpassfilterschaltung verteilter Parameter, bestehend aus Übertragungsleitungen (UE), die mit Kurzschluss-Stichleitungen (ST) zwischen einem Quellenwiderstand (Rs) und einem Lastwiderstand (RL) in Reihe verbunden sind,
- Erhöhen des Impedanzpegels der Schaltung durch Anbringen eines Wechselrichters (1) an jedem Ende der gebildeten Schaltung,
- Umwandeln der Übertragungsleitungen (UE) in äquivalente Wellenleiter (RectWG),
- Austauschen der Impedanzen an den Schaltungsenden mit Impedanzen von Wellenleitern (RectWG), die am Eingang und am Ausgang des Wellenleitertiefpassfilters mit der Trennfrequenz des Wellenleitertiefpassfilters verwendet werden,
- Umwandeln der Kurzschluss-Stichleitungen (ST) in äquivalente Hohlräume (C),
- Anpassen der Stichleitungslängen (h) auf eine Weise, um Übertragungsnullstellen bei mehr als einer Frequenz in dem Stoppband zu erzeugen,
- Anpassen von Stichleitungslängen (h) und Wellenleiterhöhen (b) und damit Anpassen der Rückflussdämpfung in dem Durchlassbereich und der Filterselektivität,
- Anzeigen des synthetisierten Filters auf dem Bildschirm.

2. Computergestütztes Konstruktionsverfahren nach Anspruch 1 und **dadurch gekennzeichnet, dass** das Produkt nach dem Schritt "Anzeigen des synthetisierten Wellenleitertiefpassfilters auf dem Bildschirm" unter Verwendung einer Produktionsvorrichtung hergestellt wird.

Revendications

1. Procédé de conception assistée par ordinateur, pour concevoir un filtre passe-bas de guide d'ondes miniature à bande, dans lequel le filtre passe-bas de guide d'ondes agit comme un filtre passe-bande en raison des caractéristiques passe-haut des guides d'ondes du filtre passe-bas de guide d'ondes, appropriées pour supprimer les signaux harmoniques et de mode d'ordre supérieur générés dans des multiplexeurs de satellites au moyen d'un dispositif électrique constitué d'une unité de mémoire stockant un logiciel de synthèse de filtre ayant une interface utilisateur graphique, une unité de processeur adaptée pour exécuter ledit logiciel de synthèse de filtre, une interface d'entrée de données pour recevoir des paramètres de conception depuis un utilisateur et un moniteur pour l'affichage graphique d'un circuit de filtre conçu et d'une simulation, dans lequel la conception de filtre passe-bande est démarrée sous la forme d'un filtre passe-bas à paramètres distribués comprenant des lignes de transmission (UE) et des tronçons de court-circuit (ST) ensuite convertis en guides d'ondes à impédance équivalente (RectWG), le procédé étant constitué de :

- Sélection des paramètres de filtre suivants via l'interface graphique du logiciel de synthèse de filtres en utilisant l'interface d'entrée des données,
    - ◦ plage de fréquences de la bande passante du filtre passe-bande,
    - ◦ plage de fréquences de la bande d'arrêt,
    - ◦ fréquence de coupure du filtre passe-bas du guide d'onde à concevoir, fréquence de longueur quart d'onde du filtre passe-bas à paramètres distribués à synthétiser,
    - ◦ largeur (a) et hauteur (b) des guides d'on-

des à utiliser dans le filtre passe-bas de guide d'ondes,

◦ nombre de lignes de transmission (UE) et de tronçons de court-circuit (ST) à utiliser dans le filtre passe-bas à paramètres distribués,

- Formation d'un circuit de filtre passe-bas à paramètres distribués constitué de lignes de transmission (UE) interconnectées en série avec des tronçons de court-circuit (ST), entre une résistance de source (Rs) et une résistance de charge (RL),
- Élévation du niveau d'impédance du circuit en plaçant un inverseur (I) à chaque extrémité du circuit formé,
- Conversion des lignes de transmission (UE) en guides d'ondes équivalents (RectWG),
- Échange d'impédances aux extrémités du circuit avec des impédances de guides d'ondes (RectWG) utilisées en entrée et en sortie du filtre passe-bas du guide d'onde à la fréquence de coupure du filtre passe-bas du guide d'onde,
- Conversion des tronçons de court-circuit (ST) en cavités (C) équivalentes,
- Ajustement des longueurs de tronçon (h) de manière à créer des zéros de transmission à plus d'une fréquence dans la bande d'arrêt,
- Ajustement des longueurs de tronçons (h) et des hauteurs de guides d'ondes (b) et donc ajustement de l'affaiblissement de réflexion en sélectivité de bande passante et filtre,
- Affichage du filtre synthétisé à l'écran.

2. Procédé de conception assistée par ordinateur selon la revendication 1 et **caractérisé en ce que** le produit est fabriqué en utilisant un dispositif de production après l'étape « Affichage du filtre passe-bas de guide d'ondes synthétisé à l'écran ».

FIGURE 1

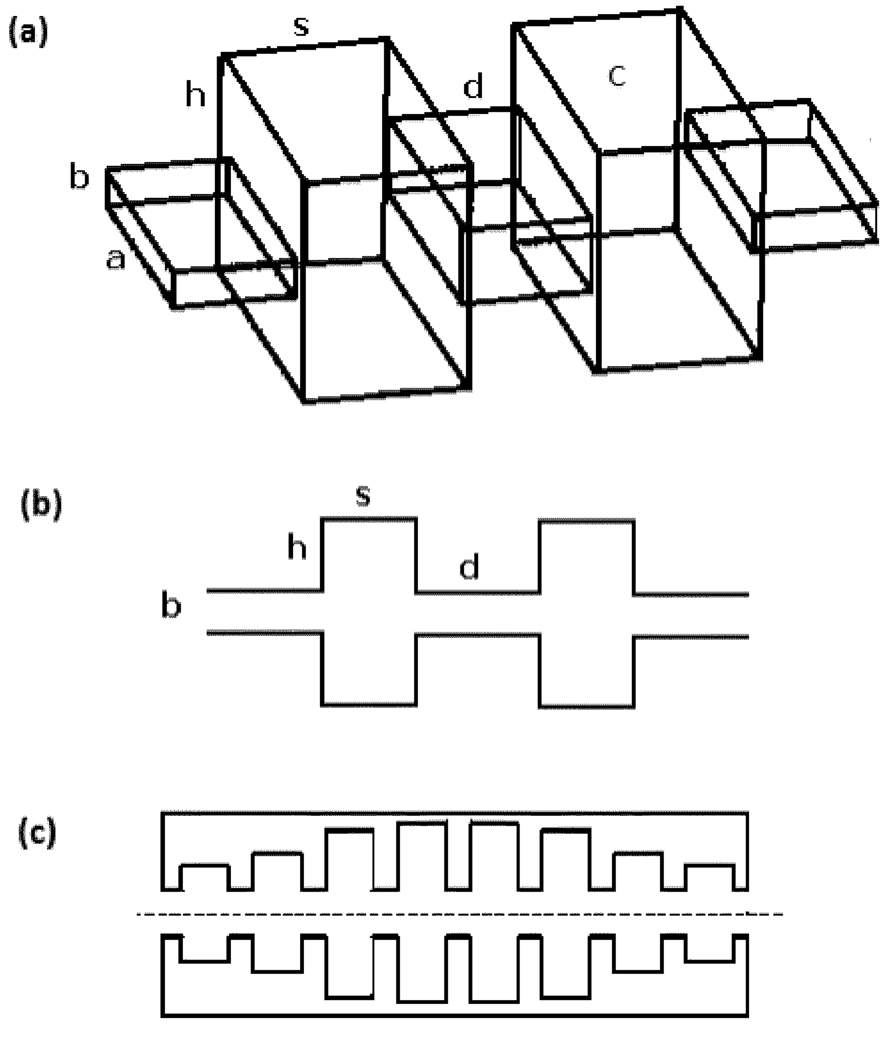


FIGURE 2

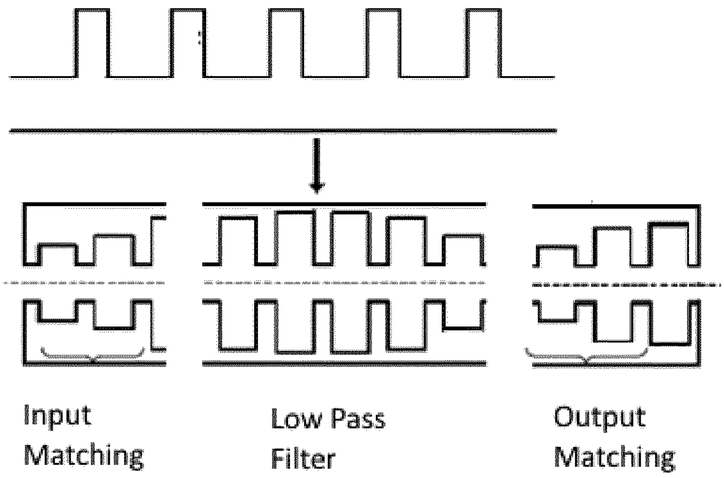


FIGURE 3

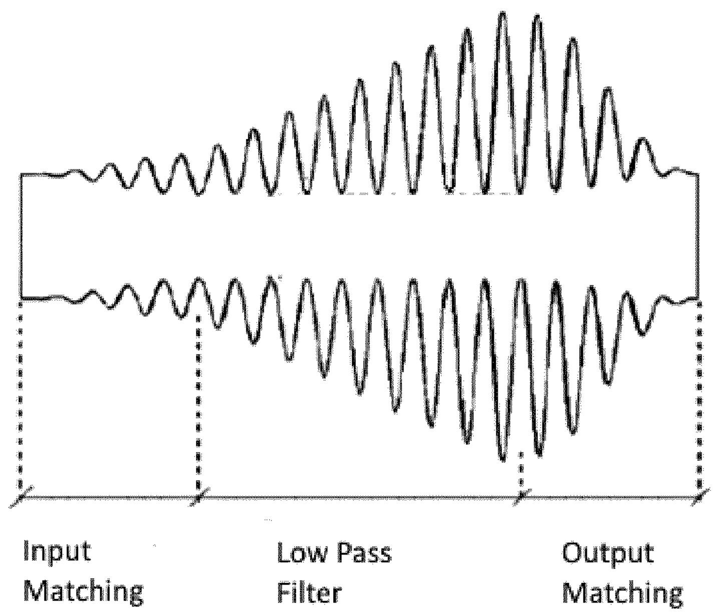


FIGURE 4

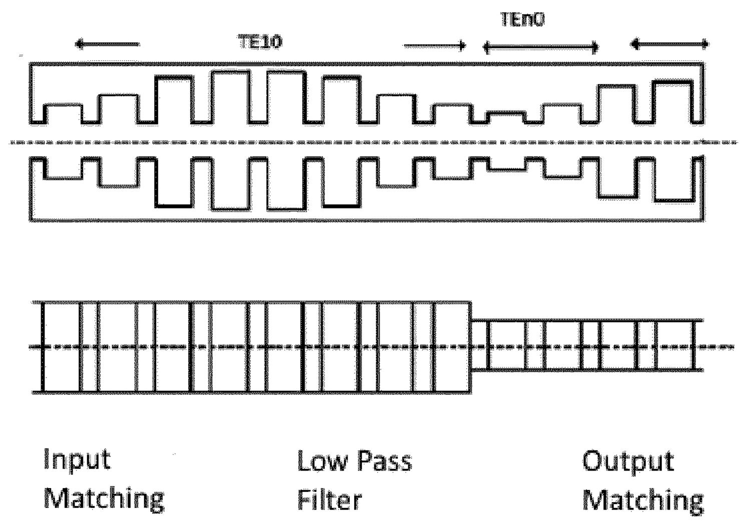


FIGURE 5

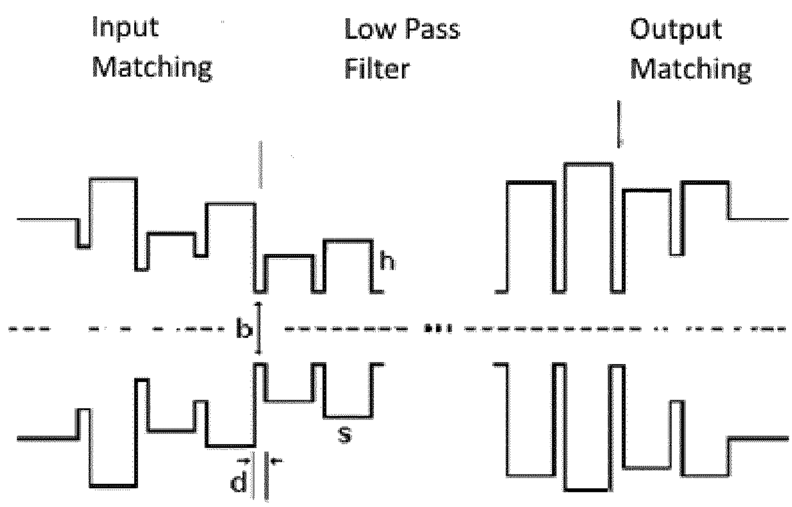
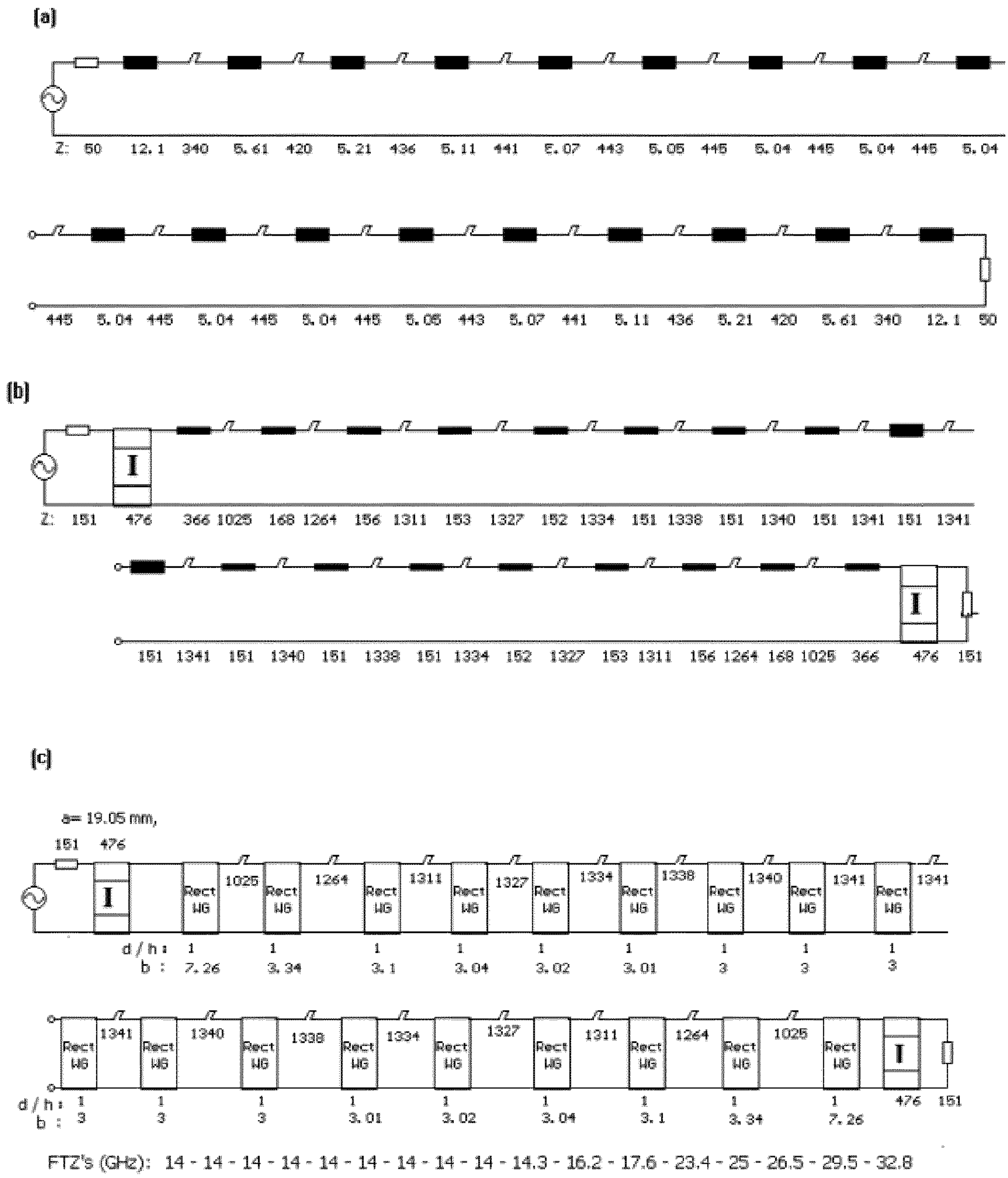
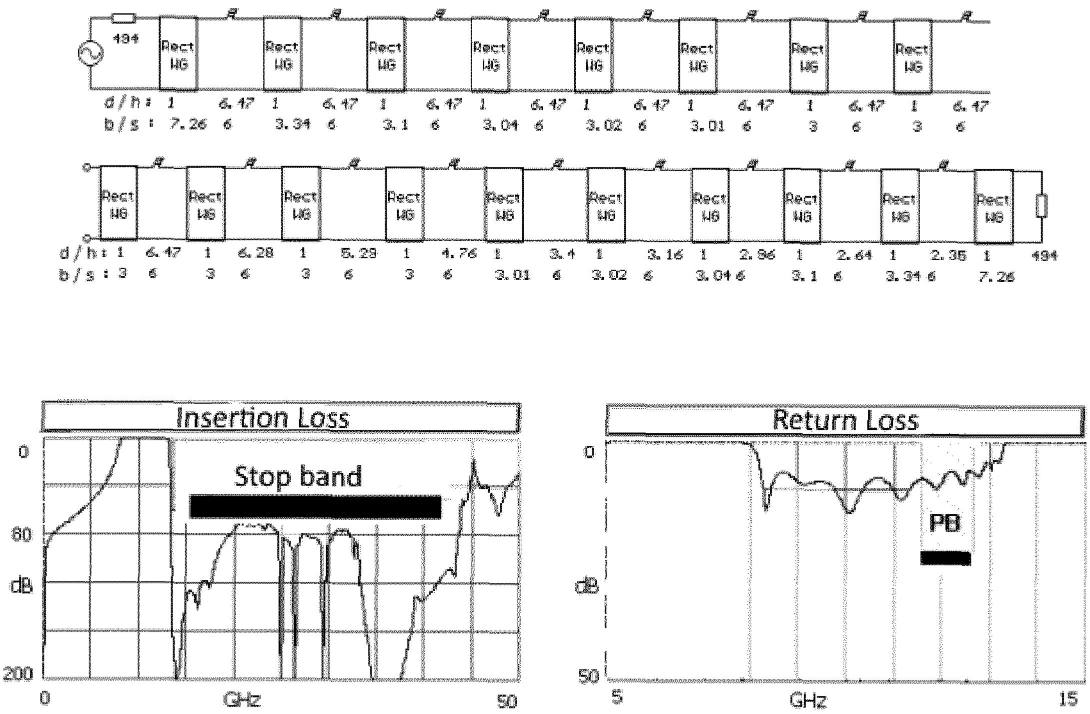


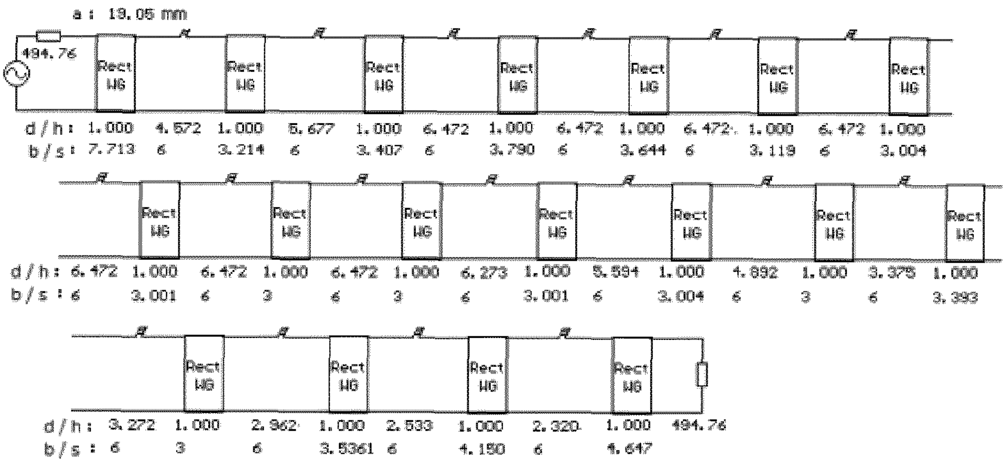
FIGURE 6

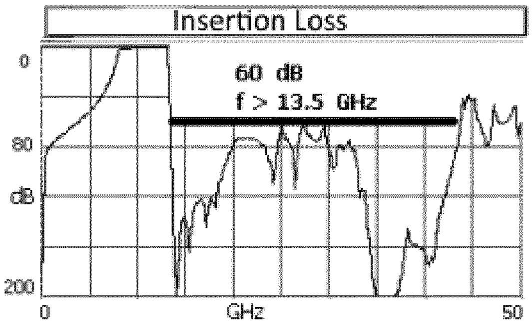

(a)
Z: 50 12.1 340 5.61 420 5.21 436 5.11 441 5.07 443 5.05 445 5.04 445 5.04 445 5.04
445 5.04 445 5.04 445 5.04 445 5.05 443 5.07 441 5.11 436 5.21 420 5.61 340 12.1 50
(b)
I
Z: 151 476 366 1025 168 1264 156 1311 153 1327 152 1334 151 1338 151 1340 151 1341 151 1341
151 1341 151 1340 151 1338 151 1334 152 1327 153 1311 156 1264 168 1025 366 476 151
(c)
a= 19.05 mm,
151 476
1025 1264 1311 1327 1334 1338 1340 1341 1341
Rect WG
d / h : 1 1 1 1 1 1 1 1 1
b : 7.26 3.34 3.1 3.04 3.02 3.01 3 3 3
1341 1340 1338 1334 1327 1311 1264 1025
d / h : 1 1 1 1 1 1 1 1 1
b : 3 3 3 3.01 3.02 3.04 3.1 3.34 7.26
476 151
FTZ's (GHz): 14 - 14 - 14 - 14 - 14 - 14 - 14 - 14 - 14 - 14.3 - 16.2 - 17.6 - 23.4 - 25 - 26.5 - 29.5 - 32.8

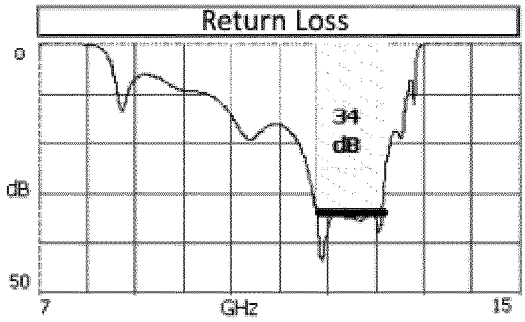
(d)


494
Rect WG
d / h : 1 6.47 1 6.47 1 6.47 1 6.47 1 6.47 1 6.47 1 6.47 1 6.47
b / s : 7.26 6 3.34 6 3.1 6 3.04 6 3.02 6 3.01 6 3 6 3 6
d / h : 1 6.47 1 6.28 1 5.29 1 4.76 1 3.4 1 3.16 1 2.96 1 2.64 1 2.35 1 494
b / s : 3 6 3 6 3 6 3 6 3.01 6 3.02 6 3.04 6 3.1 6 3.34 6 7.26
Insertion Loss
Stop band
0
60
dB
200
0
GHz
50
Return Loss
PB
0
dB
50
5
GHz
15

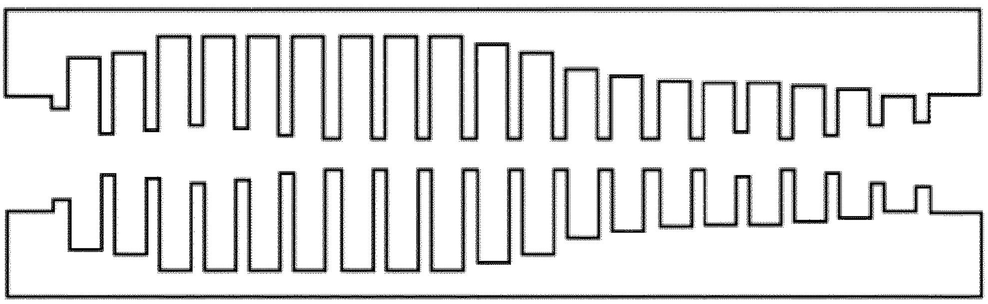
(e)


a : 19.05 mm
494.76
Rect WG
d / h : 1.000 4.572 1.000 5.677 1.000 6.472 1.000 6.472 1.000 6.472 1.000 6.472 1.000
b / s : 7.713 6 3.214 6 3.407 6 3.790 6 3.644 6 3.119 6 3.004
d / h : 6.472 1.000 6.472 1.000 6.472 1.000 6.273 1.000 5.594 1.000 4.892 1.000 3.375 1.000
b / s : 6 3.001 6 3 6 3 6 3.001 6 3.004 6 3 6 3.393
d / h : 3.272 1.000 2.962 1.000 2.533 1.000 2.320 1.000 494.76
b / s : 6 3 6 3.5361 6 4.150 6 4.647


Insertion Loss
60 dB
f > 13.5 GHz
0
80
dB
200
0
GHz
50


Return Loss
0
34
dB
dB
50
7
GHz
15

(f)



REFERENCES CITED IN THE DESCRIPTION

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