(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 477 765 A1**

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.05.2019 Bulletin 2019/18

(51) Int Cl.:
H01P 1/208 *(2006.01)* ***H01P 1/209*** *(2006.01)*

(21) Application number: **18199497.1**

(22) Date of filing: **10.10.2018**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **24.10.2017 TR 201716365**

(71) Applicant: **Aselsan Elektronik Sanayi ve Ticaret Anonim**
Sirketi
06370 Ankara (TR)

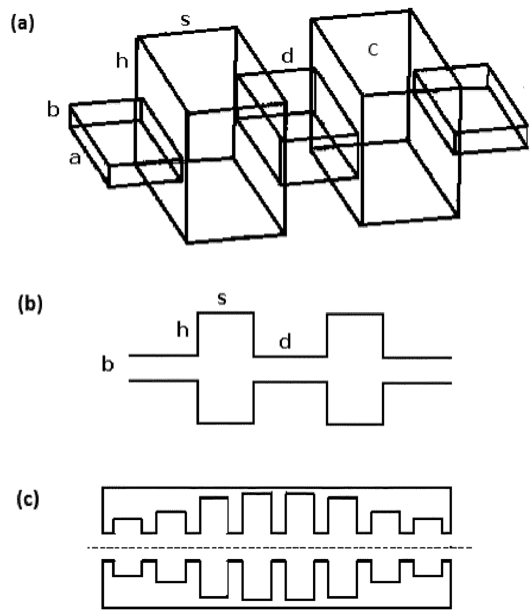
(72) Inventors:
- **YILDIRIM, NEVZAT**
  Ankara (TR)
- **ALICIO LU, BÜLENT**
  Ankara (TR)

(74) Representative: **Yamankaradeniz, Kemal**
Destek Patent, Inc.
Eclipse Business D
Blok No. 5 Maslak
34398 Istanbul (TR)

(54) KU-BAND MINIATURE WAVEGUIDE LOW PASS FILTER

(57) The invention relates to a computer aided design method for designing a Ku-Band Miniature Waveguide Low Pass Filter suppressing harmonics and higher order mode signals generated at output multiplexer in satellites. With the method disclosed under the invention, both application circuits and stop circuits can be synthesized as one single part. Thus all of circuit elements contribute to both impedance matching and suppressing. This helps shortening filter size, enhancement of selectivity and increasing rejection level. In addition, both power, cavity (C) sizes and waveguide length (d) and waveguide height (b) can be taken under control by means of developed circuit transformations. Thus power issues can be eliminated.

FIGURE 1



EP 3 477 765 A1

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 emitted in such embodiments. Basic Mode is taken as TE10. For emission of this Mode, wave frequency (f) should be higher than cut-off 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 spread only TE10 Mode. In addition, even only TE10 Mode is emitted, the power amplifiers in the system may generate harmonics (nfo) of basic frequency (fo) and such harmonics may be emitted within 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.

[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, filter degree are under control of designer. Degree restrictions arising from synthesis software and experiencing difficulties in production of component values obtained as a result of synthesis by available technologies in some cases are disadvantages of the synthesis approach.

[0006] These disadvantages of the synthesis approach have caused development of EM Optimization techniques. With these techniques, component member values and sizes realizable to design, direct EM optimization method is started and 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 to Unit Element (UE- transmission line) -Serial stub combination by use of distributed parameter circuit theory, and then transmission lines transformed into waveguide, Serial Stub into cavities. Impedance matching circuits are added to inputs and outputs of this circuit and final structures formed (Figure 2). Because of numerical error restrictions in syntheses software, element numbers remain at low levels and therefore today applications fail to meet too wide band stop specifications. Furthermore, discontinuity of step type and failure to control heights of waveguide parts (b) cause multipaction. The new design method disclosed under this patent takes the filter specifications of the said papers. 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.

[0009] 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 discontinuity in serial stub-UE steps in 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 consists of three blocks, input-output matching circuits and main filter part.

[0010] In Reference [3], LP filter is designed through EM Optimization approach entirely. The embodiment is shown in Figure 4. In this approach, E-M models of cavity and waveguides are derived in broad frequency range. Transmission Zero-TZ created by cavities are determined in EM medium by use of Y-parameters through employment of such models. Suppression band of LP filters formed by successive connection of cavities are formed by extending TZ of cavities into band. Number of modules is selected subject to suppression quantity and suppression band width. E-M optimization is started by selecting both waveguide parts and sizes of cavities. Sizes are selected in a manner not causing power restriction issue.

[0011] The embodiment shown in Figure 4 consists 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.

[0012] 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.

[0013] 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 of both matching circuits and main filter similar cavity and waveguide separating them. 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 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.

[0014] Selectivity of filter is adjusted in a manner to create TZ on multiple Number of cavity heights (h) pass band edge and thus high values are achieved. 13.5 - 40 GHz rejection of filter designed by this approach is higher than 60 dB. 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).

References

[0015] R. Levy, "Compact waveguide bandstop filters for wide stopbands," IEEE MTT-S Int. Dig., Boston, MA, 2009, pp. 1245-1248.

[0016] I. Arregui, I. Arnedo, A. Lujambio, M. Chudzik, D. Benito, R. Jost, F. Gortz, T. Lopetegi, and M. A. G. Laso, "A compact design of high-power spurious-free low-pass waveguide filters," IEEE Microw. Wireless Compon. Lett., vol. 20, no. 11, pp. 595-597, Nov. 2010.

[0017] F. D. Paolis; R. Goulouev; J. Zheng; M. Yu, "CAD Procedure for High-Performance Composite Corrugated Filters", IEEE MTT, Year: 2013, Volume: 61, Issue: 9, PLPes: 3216 - 3224.

[0018] F.Teberio, I.Arregui, A.G. Torrent, E.Menargues, I. Arnedo, M. Chudzik, M. Zedler, F.J. Gört, R. Jost, T. Lopetegi, M. A.G.Laso,"Low-loss compact Ku-band waveguide low-pass filter," IEEE MTT-S, Phoenix, AZ, 2015.

Problems Solved by the Invention

[0019] 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 Low Pass Filter suppressing at least 60 dB up to 40 GHz.

[0020] In the new approach developed it is started with new software capable to synthesize very high order filters to filter design, and all capabilities and advantages of synthesis approach are used to the full level and EM Optimization is started after reaching to close to targeted structure and specification. Thus advantages of both approaches are used to the fullest level.

[0021] 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, entire filter, that is both matching and suppressing circuits can be synthesized as one single part. Thus all of circuit elements contribute to both impedance matching and suppressing. 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.

[0022] 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 much more controlled and easy to design designs of better ones of the filters developed in other reference publications using E-M Optimization approach are possible with this synthesis method.

[0023] 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 Return Loss in pass band contribute to impedance matching of all of elements, much higher levels in comparison to other approaches can be achieved.

- Power multipaction problem can be recovered.

- Rejection at 14-40 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.

Detailed Description of the Invention

[0024] In order to achieve the purpose of the invention, the invention is a computer aided design method as shown 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.

[0025] 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. Waveguide
FTZ. Finite transmission zero
Z. Impedance value
PB. Pass band

[0026] 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 consists of steps of;

- Selection of filter parameters via graphical interface of filter synthesis program by use of data input interface,

- Forming a distributed parameter low pass circuit consisting of transmission lines (UE) interconnected in serial between a source resistance (Rs) and a load resistance (RL) and short circuit stubs (ST),

- Raising circuit impedance level by locating an inverter (I) on each end of formed circuit,

- Conversion of transmission lines (UE) in circuit to equivalent waveguides (RectWG),

- exchange of impedances at circuit ends with impedance at corner frequency of waveguide (RectWG) used at input and output of filter,

- Conversion of stubs (ST) at circuit into equivalent cavities (C),

- 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.

[0027] 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.

[0028] 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.

[0029] In this new approach, a Band Pass filter design is started in 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]).

[0030] 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 (E) and stubs (ST) into equivalent waveguides (RectWG) and thus forming initial circuit in figure 6d, adjustment of waveguide heights (b) and stub lengths (h) and thus achievement of targeted values in pass ad stop bands (stop > 60 dB and reflection loss > 34dB) in figure 6e.

[0031] 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, 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: f_{s1}=13500 MHz, f_{s2} = 40000 MHz. Specifications of 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, f_q is quarter wave length frequency of low pass filter in transmission line (UE) - stub (ST) embodiment to be synthesized. When this frequency is transformed into filter circuit waveguide (RectWG) structure by trials, rectangular section waveguide (RectWg) size is selected to be 1 mm (millimeter) and shorter or longer value can also be selected.

[0032] Input and output of the filter is ended with WR75 type waveguides (RectWG). Width (a) of said waveguides to be used at inputs and outputs of filter is 19.05 mm, height (b)waveguides is 9.525 mm. Width (a) of other waveguides inside filter (except inputs and outputs) is 19.05 mm height (b) of waveguides is variable and minimum value is taken as 3 mm in order to prevent multipaction.

[0033] Numbers of transmission line (UE) and stub (ST) forming low pass filter are: N_{ue}=18 ve N_{stub}=17. Thus degree of filter is selected as N= 17 + 18 = 35.

[0034] After determination of parameters to be used in design, selected circuit elements are used to start filter design stage. In an illustrative application of the invention, selected circuit elements are interconnected serially, namely, as transmission line (UE) + stub (ST) + transmission line (UE) + stub (ST) + ..., and a low pass circuit of distributed parameter as shown in figure 6a is synthesized by means of forming between a source resistance (Rs) and a load resistance (RL). Impedance values (Z) of circuit elements are given separately under related circuit elements.

[0035] In the next step, one inverter (I) is placed each of both ends of circuit and circuit impedance level is increased. In an illustrative application of the invention, one inverter (I) is placed on each of circuit ends in a manner dimensions of waveguide (RectWG) are width (a) of waveguide is 19.05 mm, height (b) of waveguide is 3 mm for guide part in the very middle of circuit.

[0036] Transmission lines (UE) in circuit in next step is converted into equivalent waveguide (RectWG) (Figure 6c). Then impedances at circuit ends exchange with impedance of a certain frequency of waveguide (RectWG) used at input and output of filter, In an illustrative application of the invention, impedances at said circuit ends, of f_{p2}=12700 MHz for said waveguide (RectWG) of width (a) of waveguide 19.05 mm and height (b) of waveguide 9.525 mm (selected from interface, corner frequency of band pass filter) is changed as R= 494.76 Ohm (Figure 6d). Selection of frequency as f_{p2} here is to prevent deformation of band pass filter on upper edge and facilitate further optimization works. Also short circuit stubs (ST) in this step are converted into equivalent cavities (C) (waveguide type stubs (ST)). During or before such conversion, stub lengths (h) are adjusted in a manner to create Transmission Zero-TZ) at various frequencies (Figure 6d). Distribution within the stop band (between 13500 MHz - 40000 MHz) of transmission zero is manually adjusted to given stop higher than 60 dB by means of a number of iterations.

[0037] 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 length (d) is given in upper line under waveguides (RectWG) while waveguide height (b) is shown in lower line. Said stub lengths (h) (cavity heights) and waveguide heights (b) are adjusted and both return loss in low pass band (f_{p1}=11600 MHz, f_{p2}=12700 MHz) and filter selectivity can be adjusted. For instance, stub lengths(h) and waveguide heights (b) in figure 6d are manually adjusted and as shown in Figure

6e, both pass band return loss is increased to 34 dB and stop of 60 dB is obtained at stop band.

[0038] In final step, synthesized filter is shown on the screen. In an 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]).

[0039] 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).

[0040] 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, in the most basic form, for designing a Ku-Band Miniature Waveguide Low Pass Filter 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 user and a monitor for graphical display of designed circuit and simulation and it is **characterized in that** it consists of;

   - Selection of filter parameters via graphical interface of filter synthesis program by use of data input interface,
   - Forming a distributed parameter low pass circuit consisting of transmission lines (UE) interconnected in serial between a source resistance (Rs) and a load resistance (RL) and short circuit stubs (ST),
   - Raising circuit impedance level by locating an inverter (I) on each end of formed circuit,
   - Conversion of transmission lines (UE) in circuit to equivalent waveguides (RectWG),
   - exchange of impedances at circuit ends with impedance at corner frequency of waveguide (RectWG) used at input and output of filter,
   - Conversion of stubs (ST) at circuit into equivalent cavities (C),
   - 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 returnloss in pass band and selectivity of filter,
   - Display of synthesized filter on screen.

2. A computer aided design method according to claim 1 and it is **characterized in that** in the step of "election of filter parameters via graphical interface of filter synthesis program by use of data input interface",

   - frequency range of pass band of a band pass filter,
   - frequency range of stop band,
   - cutoff frequency of low pass filter to be designed, quarter wave length frequency of low pass filter in transmission line (UE) - stub (ST) embodiment to be synthesized,
   - Width (a) of waveguides to be used in filter and height (b) of waveguides,
   - Number of transmission line (UE) and stubs (ST) to be used in filter are selected.

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

4. A circuit produced by use of a computer aided design method according to claim 3.

FIGURE 1

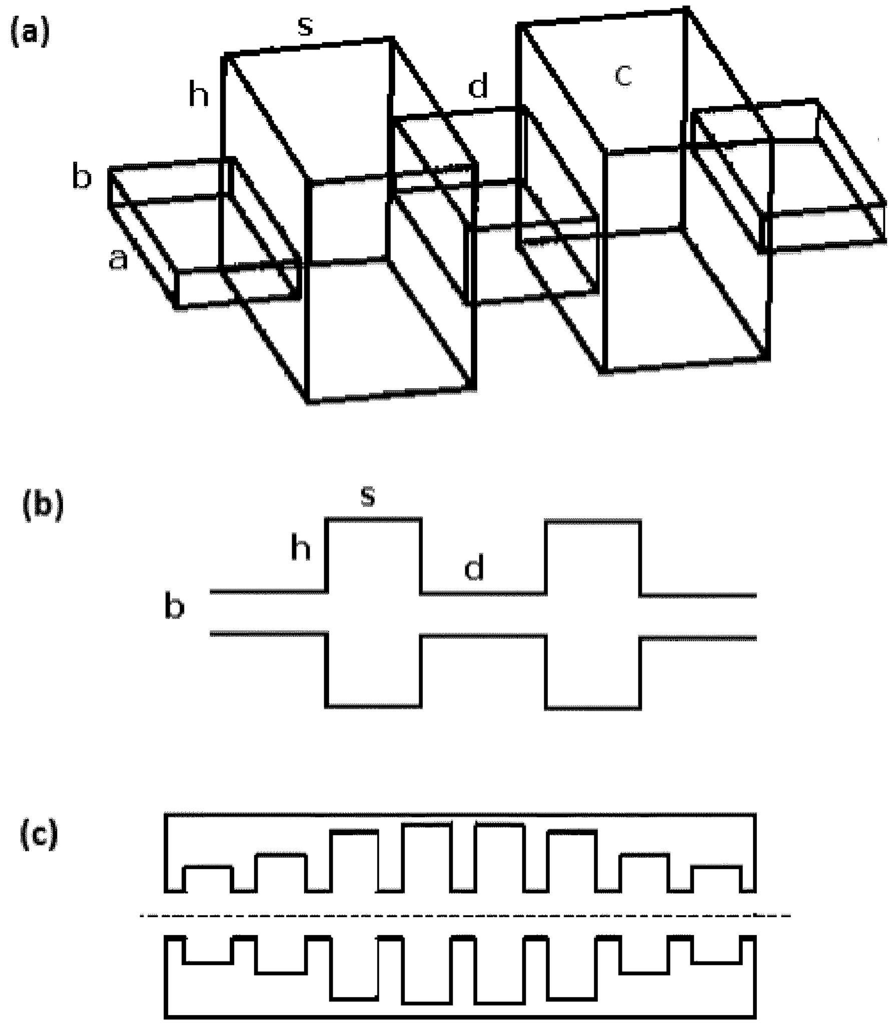


FIGURE 2

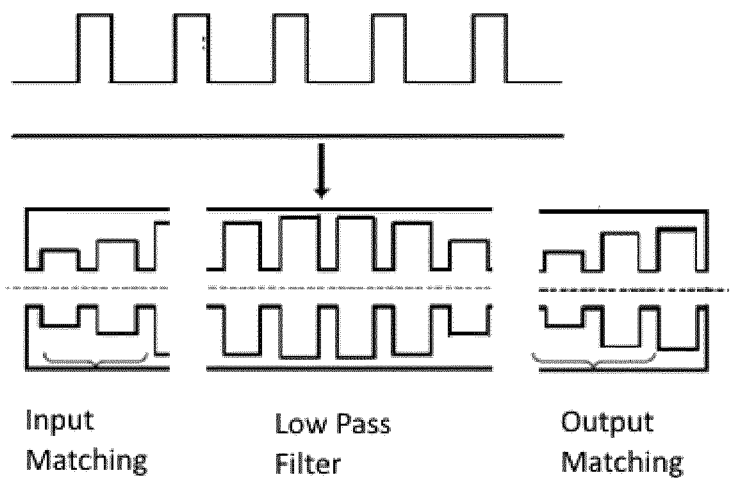


FIGURE 3

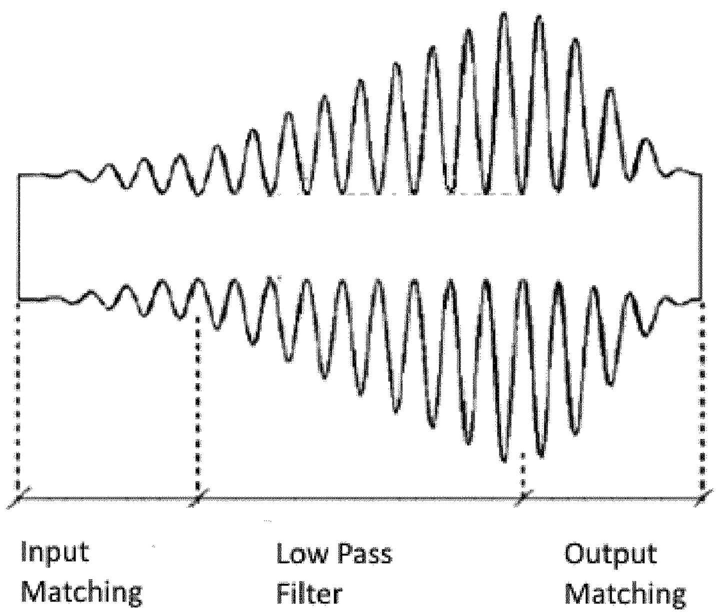


FIGURE 4

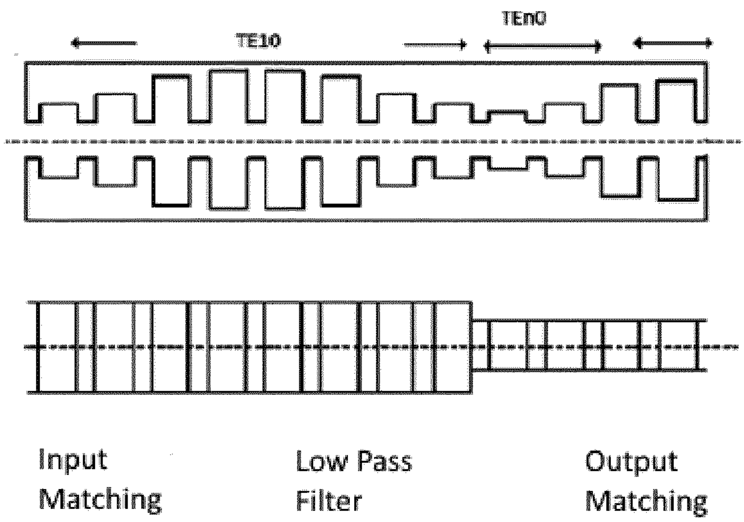


FIGURE 5

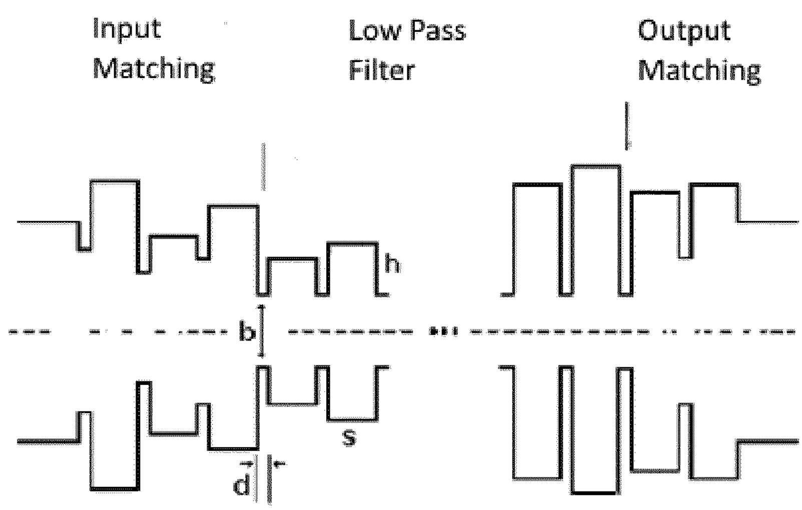
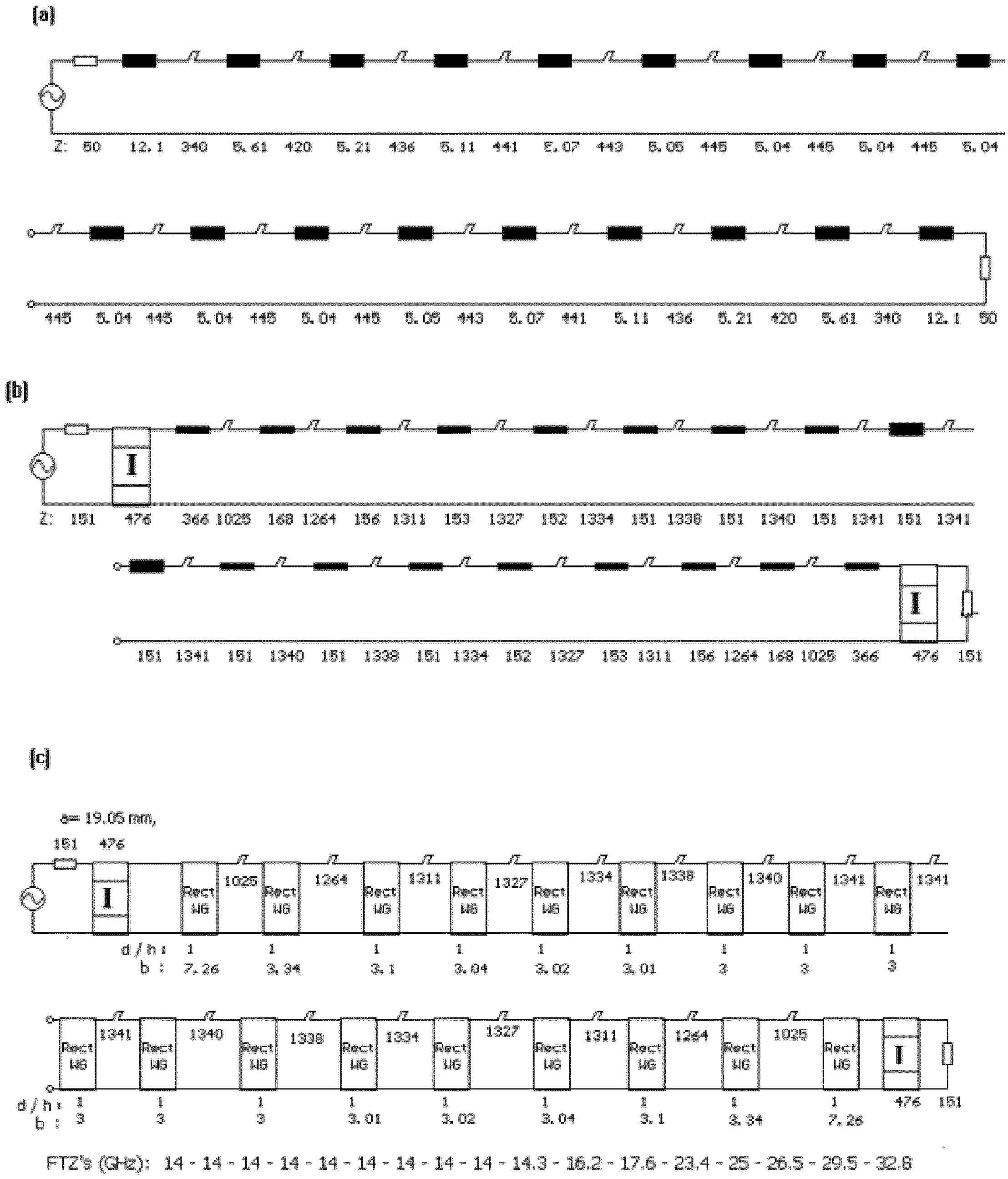
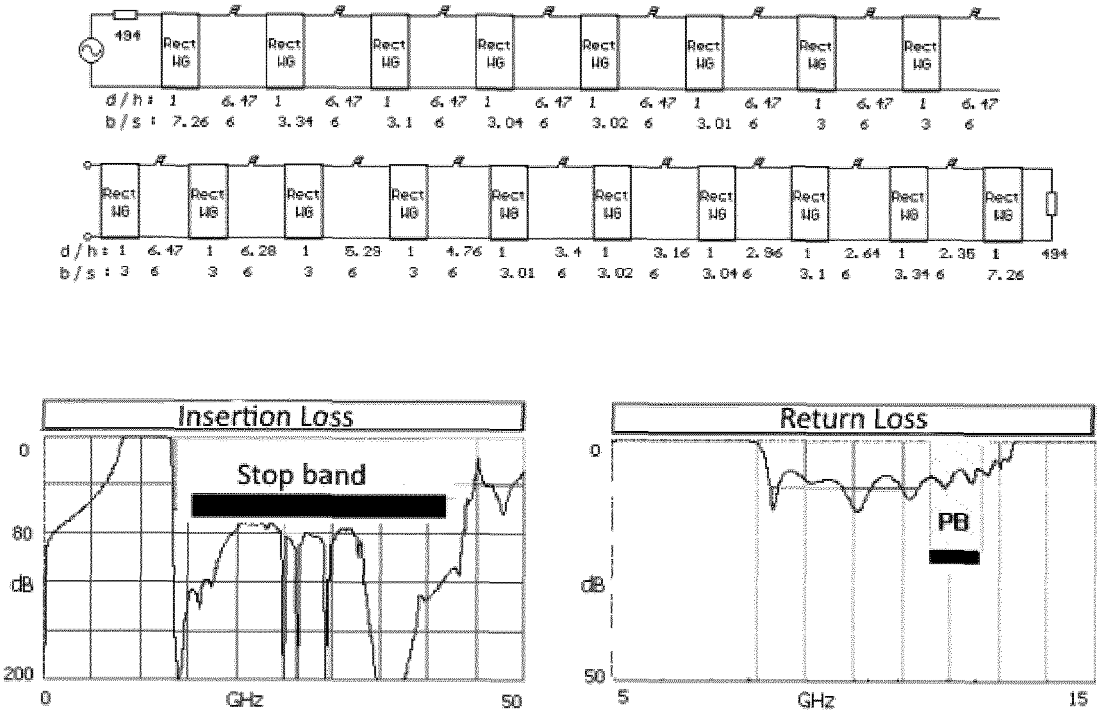


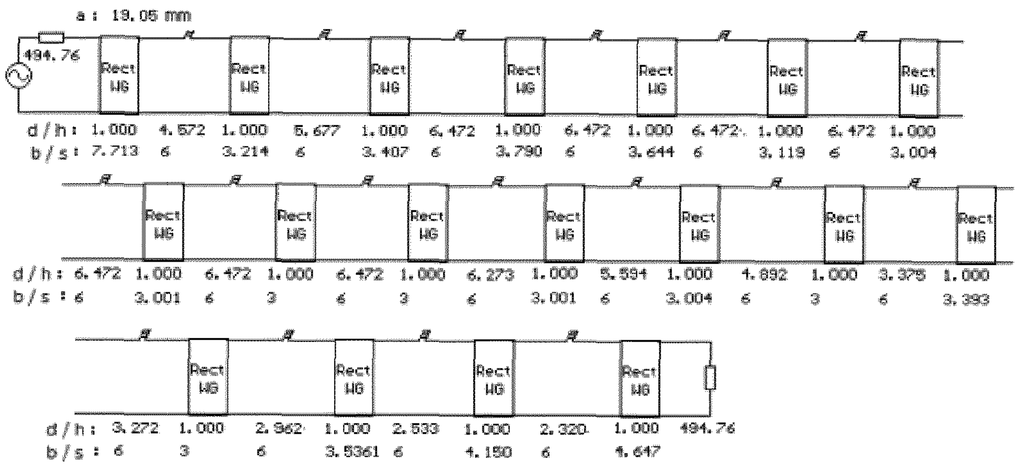
FIGURE 6

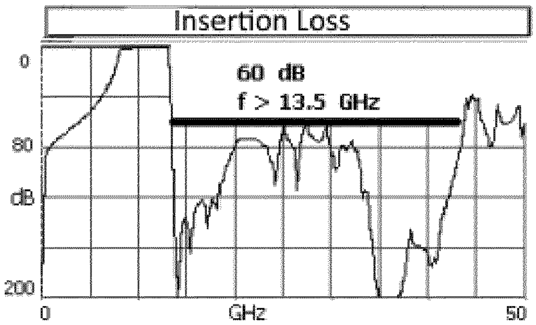

(a)
Z: 50 12.1 340 5.61 420 5.21 436 5.11 441 5.07 443 5.05 445 5.04 445 5.04 445 5.04
445 5.04 445 5.04 445 5.04 445 5.05 443 5.07 441 5.11 436 5.21 420 5.61 340 12.1 50
(b)
I
Z: 151 476 366 1025 168 1264 156 1311 153 1327 152 1334 151 1338 151 1340 151 1341 151 1341
151 1341 151 1340 151 1338 151 1334 152 1327 153 1311 156 1264 168 1025 366 476 151
(c)
a= 19.05 mm,
151 476
I
Rect WG
1025 1264 1311 1327 1334 1338 1340 1341 1341
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 1 476 151
b : 3 3 3 3.01 3.02 3.04 3.1 3.34 7.26
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

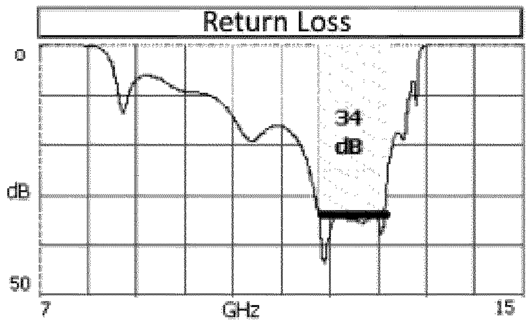
(d)


Rect WG
Insertion Loss
Stop band
dB
GHz
Return Loss
PB

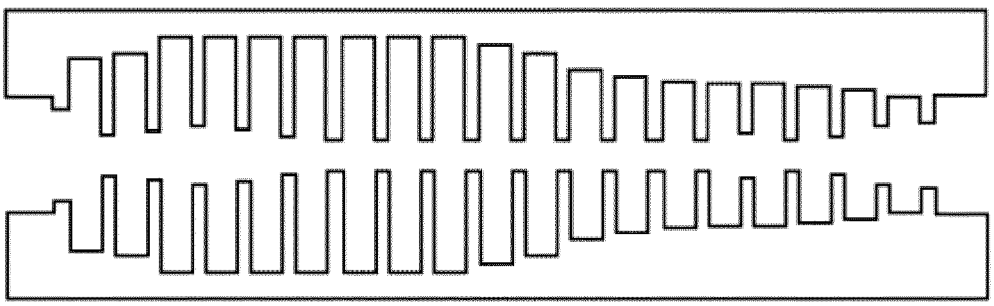
(e)


a : 19.05 mm
Rect WG


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)



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 19 9497

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y,D	DE PAOLIS FABRIZIO ET AL: "CAD Procedure for High-Performance Composite Corrugated Filters", IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, PLENUM, USA, vol. 61, no. 9, 1 September 2013 (2013-09-01), pages 3216-3224, XP011525391, ISSN: 0018-9480, DOI: 10.1109/TMTT.2013.2275451 [retrieved on 2013-08-30] * the whole document * -----	1-4	INV. H01P1/208 H01P1/209
Y	Nevzat Yildirim: "Ch13-v74-WGFilts - Chapter 13: Waveguide filters", , 15 February 2017 (2017-02-15), pages 13-1-13-133, XP002789289, Retrieved from the Internet: URL:http://users.metu.edu.tr/nyil/manual/ [retrieved on 2019-02-27] * the whole document * -----	1-4	
			TECHNICAL FIELDS SEARCHED (IPC)
A	Nevzat Yildirim: "Index of Manual of Filpro Software", , 15 February 2017 (2017-02-15), XP002789301, Retrieved from the Internet: URL:http://users.metu.edu.tr/nyil/manual/ [retrieved on 2019-02-27] * the whole document * ----- -/--	1-4	H01P

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	5 March 2019	La Casta Muñoa, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

page 1 of 2

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 19 9497

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	SNYDER R V ED - INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS: "GENERALIZED CROSS-COUPLED FILTERS USING EVANESCENT MODE COUPLING ELEMENTS", 1997 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST. DENVER, JUNE 8 - 13, 1997; [IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST], NEW YORK, NY : IEEE, US, 8 June 1997 (1997-06-08), pages 1095-1098, XP000767685, ISBN: 978-0-7803-3815-9 * abstract * -----	1-4	
A	SNYDER RICHARD V ET AL: "Present and Future Trends in Filters and Multiplexers", IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, PLENUM, USA, vol. 63, no. 10, 1 October 2015 (2015-10-01), pages 3324-3360, XP011670688, ISSN: 0018-9480, DOI: 10.1109/TMTT.2015.2475245 [retrieved on 2015-10-02] * abstract * -----	1-4	TECHNICAL FIELDS SEARCHED (IPC)
X,P	CETIN METEHAN ET AL: "Synthesis Approach for Compact Ku-Band Waveguide Lowpass Filters with Wide Rejection Bandwidth", 2018 18TH MEDITERRANEAN MICROWAVE SYMPOSIUM (MMS), IEEE, 31 October 2018 (2018-10-31), pages 221-224, XP033499497, DOI: 10.1109/MMS.2018.8611878 [retrieved on 2019-01-14] * abstract * -----	1-4	

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	5 March 2019	La Casta Muñoa, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

page 2 of 2

REFERENCES CITED IN THE DESCRIPTION

Non-patent literature cited in the description

- **R. LEVY.** Compact waveguide bandstop filters for wide stopbands. *IEEE MTT-S Int. Dig.,* 2009, 1245-1248 **[0015]**
- **I. ARREGUI ; I. ARNEDO ; A. LUJAMBIO ; M. CHUDZIK ; D. BENITO ; R. JOST ; F. GORTZ ; T. LOPETEGI ; M. A. G. LASO.** A compact design of high-power spurious-free low-pass waveguide filters. *IEEE Microw. Wireless Compon. Lett.,* November 2010, vol. 20 (11), 595-597 **[0016]**
- **F. D. PAOLIS ; R. GOULOUEV ; J. ZHENG ; M. YU.** CAD Procedure for High-Performance Composite Corrugated Filters. *IEEE MTT, Year,* 2013, vol. 61 (9), 3216-3224 **[0017]**
- **F.TEBERIO ; I.ARREGUI ; A.G. TORRENT ; E.MENARGUES ; I. ARNEDO ; M. CHUDZIK ; M. ZEDLER ; F.J. GÖRT ; R. JOST ; T. LOPETEGI.** Low-loss compact Ku-band waveguide low-pass filter. *IEEE MTT-S, Phoenix, AZ,* 2015 **[0018]**