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(54) **Structure of LOW-PASS filter in particular for DVBT-DVBH**

(57) A structure of a LOW-PASS filter, in particular for DVBT-DVBH, comprining a first STOP BAND filter with narrow band with insertion loss of <1.5dB across the transmitted band, an insertion loss at 790MHZ or 702MHz of <8dB, and an insertion loss at 739MHz or at 705MHz of >30dB followed by a second filter, in cascade, that can increase the insertion loss from 790 to 793MHz.

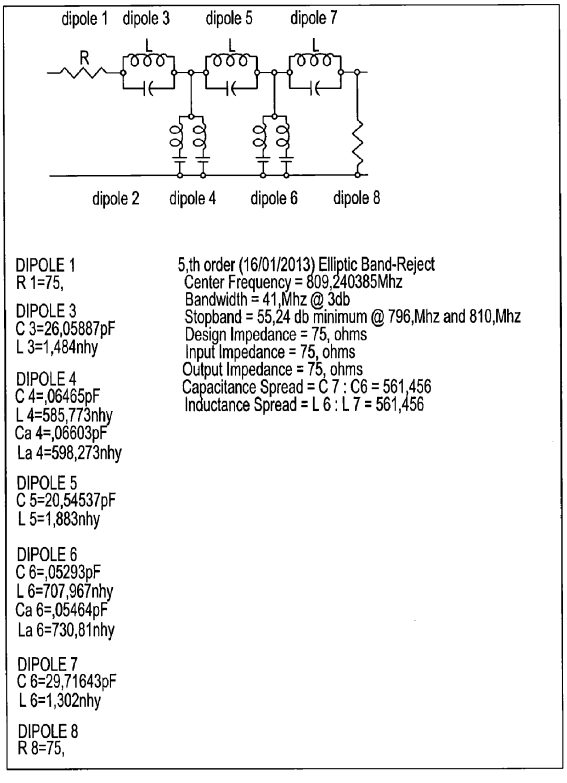

FIG. 1

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Description

BACKGROUND OF THE INVENTION

[0001] This device is a structure of Low-pass filter in particular for DVBT-DVBH.

[0002] The continuous progress of the mobile telephony has created new broadband access systems - LTE - with objective to achieve wireless high speed connections.

[0003] The frequency allocation of the LTE (Long Term Evolution) has reduced the number of available TV channels in the UHF frequency band.

[0004] In fact, the original 49 TV channels will be reduced to 40 in order to free the frequencies from 794 MHz to 858 MHz (TV channels 61 to 69).

[0005] So the LTE frequency band and TV frequency band will be adjacent with important development.

[0006] The LTE signal transmitted by the BTS will be received by the Mast Head amplifiers or the TV sets with built-in digital tuner covering the full UHF frequency band (including the 9 channels assigned to the LTE).

[0007] The total signal received at the input of the Mast Head amplifier (TV & LTE signal), in some cases, can exceed the maximum power input threshold of the amplifier, overloading the same and, because the amplifiers are not designed for excessive overloading signals, degradation/cancellation of the TV channels can occur.

[0008] This is particularly true for the TV sets receiving the adjacent signals to the DVBT band, mainly ch.60 that, exceeding some pre-set protection levels, will produce some degradation between the last DVBT channels and the first LTE frequency blocks.

[0009] The degradation of the TV signal due to the overloading of the Mast Head amplifier requires an adjustment of the domestic TV installation as per CEI regulations.

[0010] If this adjustment is not implemented, all the domestic Mast Head amplifiers shall be switched off.

SUMMARY OF THE INVENTION

[0011] In order to solve this problem, a filter shall be developed that will overcome this problem complying with CEI regulations about the LTE filters.

[0012] This development, together with other objectives, that will be clearer at later stage, is achieved with a LOW-PASS filter, in particular for DVBT-DVBH.

[0013] The filter structure is designed with a first STOP BAND filter with narrow band with insertion loss of <1.5dB across the transmitted band, an insertion loss at 790MHZ or 702MHz of <8dB, and an insertion loss at 739MHz or at 705MHz of >30dB followed by a second filter, in cascade, that can increase the insertion loss from 790 to 793MHz.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Other characteristics and advantages of this device will be clearer during the analysis of the description of the preferred but not exclusive design of this device, illustrated in the attached drawings - this illustration is indicative and not limitative:

Fig. 1 shows the equivalent circuit of the first filter;
Fig. 2 shows the frequency response of the first filter;
Fig. 3 shows the equivalent circuit of the second filter;
Fig. 4 shows the equivalent circuit of every single resonator with distributed parameters;
Fig. 5 shows the equivalent circuit of the next filter;
Figs. 6 and 7 show two graphs with LTE curve response obtained with traditional filters and the response obtained with LOW PASS filter that is part of this patent application.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] As described in the introduction, it will be almost impossible to design a filter to comply with new norms and regulations.

[0016] A new LOW PASS FILTER shall be design with very tight specifications:

1st SPECIFICATION

1. Insertion loss in the transmitted band <1.5dB
2. Insertion Loss at 790Mhz <8dB
3. Insertion loss at 793Mhz >30dB
4. Insertion loss from 830Mhz >30dB

2nd SPECIFICATION

1. Insertion loss in the transmitted band <1.5dB
2. Insertion loss at 702Mhz <8db
3. Insertion loss at 705Mhz >30dB
4. Insertion loss from 830Mhz >30dB

[0017] A single Low Pass Filter cannot be designed due to the high number of cavities required even if with an elliptical type of filter. In fact the filter shall work across the 470-950 MHz band.

[0018] According to this invention, the solution is to utilize 2 STOP BAND FILTERS in cascade: the first filter with very narrow band to satisfy the requirements 1 to 3, the second, in cascade, must provide a very sharp side to improve the insertion loss from 790 MHz to 793 MHz.

[0019] To satisfy point 4 of the specifications the first filter shall have an equivalent circuit as per Fig. 1.

[0020] Fig. 2 shows the frequency response of the filter.

[0021] This filter has only 5 cavities with these results:

Insertion loss in band <1dB;

Insertion loss at 790 MHz = -5.5dB;
Insertion loss at 793MHz = -26dB;
Bandwidth @ 3dB = 40MHz.

[0022] To improve the sharpness, an additional cavity was added to the original design.

[0023] The second filter is a Stop Band filter with a bandwidth greater than 150MHz and cannot be designed as the first one.

[0024] However the best results, to achieve the objectives for point 1 to 3, will require reducing the bandwidth of the filter to 10MHz.

[0025] With similar performances, the losses must be very low, Q factors of the resonators very high and coupling factors very weak.

[0026] So the filter had to be designed with distributed parameters.

[0027] Every parallel resonator has been replaced by an inverter (750hm line impedance with a 90° phasor at the centre of the band of the filter) followed by a cascade resonator with high Q made by a $\lambda/4$ coax line with centre frequency 796MHz terminated to earth and to a capacitor.

[0028] In order to keep a high Q factor for each resonator, the matching is made with matched coax.

[0029] Fig. 3 shows this solution.

[0030] Every INV block is made by a 75Ω line whose length is calculated for the correct operation of the filter.

[0031] Every single resonator is made by distributed parameters. Here below is the typical description of the circuits.

[0032] Every resonator is matched to the next one with a 75Ω line whose length creates a bipolar inverter.

[0033] Practically after the inverter a cascade resonant circuit appears as parallel and vice versa. This solution allows using the same type of resonator for all the cells.

[0034] This filter cannot satisfy point 4 of the specifications so a second Stop Band Filter, with same characteristics, shall be connected in cascade. The equivalent circuit is shown in Fig. 5.

[0035] The very important matching with a capacitor towards the resonators greatly reduces the Q factor and increases the rejected band beyond 150MHz.

[0036] This solution satisfies the required objectives of the project.

[0037] In fact the structure of the filter is made with 2 filters in cascade satisfying points 1 to 4 of the specifications.

[0038] Any materials, components and dimensions can be used according to the requirements.

Claims

1. A structure of a LOW-PASS filter, in particular for DVBT-DVBH is designed with a first STOP BAND filter with narrow band with insertion loss of <1.5dB across the transmitted band, an insertion loss at 790MHZ or 702MHz of <8dB, and an insertion loss at 739MHz or at 705MHz of >30dB followed by a second filter, in cascade, that can increase the insertion loss from 790 to 793MHz.

2. A LOW-PASS filter structure, according to claim 1, **characterized in that** it is realized with distributed parameters.

3. A LOW-PASS filter structure, according to claim 1, **characterized in that** it includes several inverters each one followed by a resonator in cascade.

4. A LOW-PASS filter structure, according to claim 1, **characterized in that** every resonator in cascade is made by a high Q resonator made with a $\lambda/4$ coax line with centre frequency 796MHz terminated to earth and to a capacitor.

5. A LOW-PASS filter structure, according to any of the previous claims, **characterized in that** each resonator coupling is distributed with a matched coax.

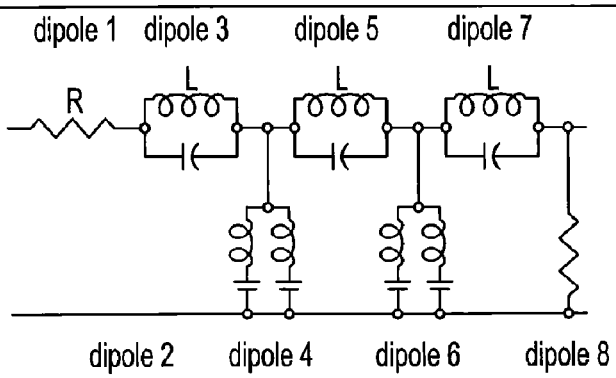
6. A LOW-PASS filter structure, according to any of the previous claims, **characterized in that** it includes several INV blocks, each one being made by a 75Ω line whose length is calculated for the correct operation of the filter.

7. A LOW-PASS filter structure, according to any of the previous claims, **characterized in that** each resonator is realized with distributed parameters.

8. A LOW-PASS filter structure, according to any of the previous claims, **characterized in that** each resonator is matched to the next with a 75Ω line with appropriate length to realize a bipolar inverter.

9. A LOW-PASS filter structure, according to any of the previous claims, **characterized in that** it comprises the same type of resonator for all the cells.

10. A LOW-PASS filter structure, according to any of the previous claims, **characterized in that** the second stop band filter is realized with distributed constants coupled to the resonators via a capacitor.



DIPOLE 1
R 1=75,

DIPOLE 3
C 3=26,05887pF
L 3=1,484nhy

DIPOLE 4
C 4=,06465pF
L 4=585,773nhy
Ca 4=,06603pF
La 4=598,273nhy

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L 5=1,883nhy

DIPOLE 6
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L 6=707,967nhy
Ca 6=,05464pF
La 6=730,81nhy

DIPOLE 7
C 6=29,71643pF
L 6=1,302nhy

DIPOLE 8
R 8=75,

5,th order (16/01/2013) Elliptic Band-Reject
Center Frequency = 809,240385Mhz
Bandwidth = 41,Mhz @ 3db
Stopband = 55,24 db minimum @ 796,Mhz and 810,Mhz
Design Impedance = 75, ohms
Input Impedance = 75, ohms
Output Impedance = 75, ohms
Capacitance Spread = C 7 : C6 = 561,456
Inductance Spread = L 6 : L 7 = 561,456

FIG. 1

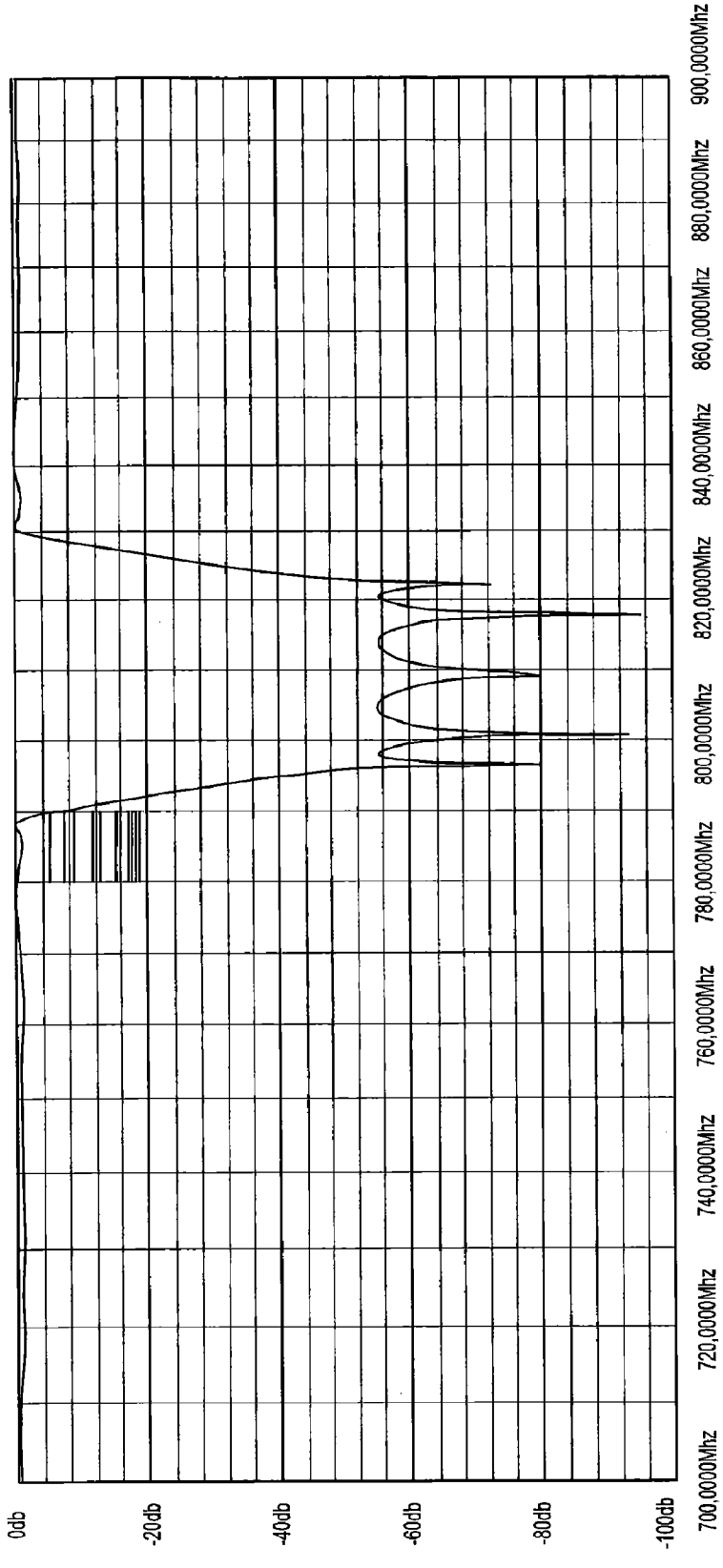
0db
-20db
-40db
-60db
-80db
-100db
700,0000Mhz
720,0000Mhz
740,0000Mhz
760,0000Mhz
780,0000Mhz
800,0000Mhz
820,0000Mhz
840,0000Mhz
860,0000Mhz
880,0000Mhz
900,0000Mhz
4,db/div by 10,0000Mhz/div
(16/01/2013) Elliptic Band-Reject

FIG. 2

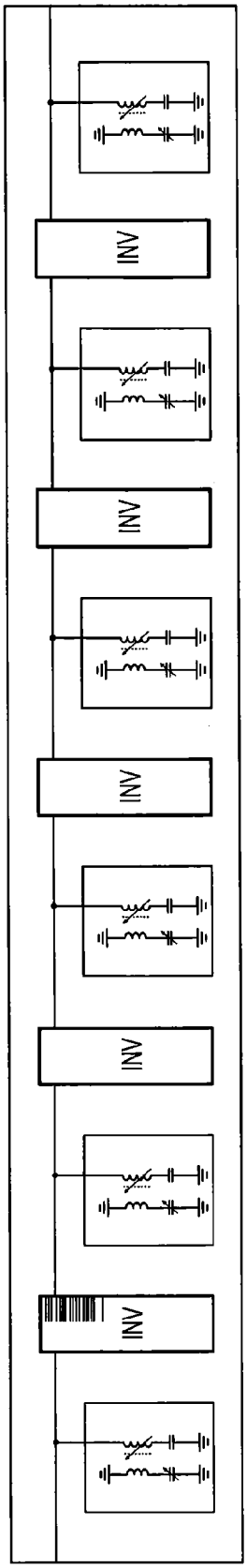

FIG. 3

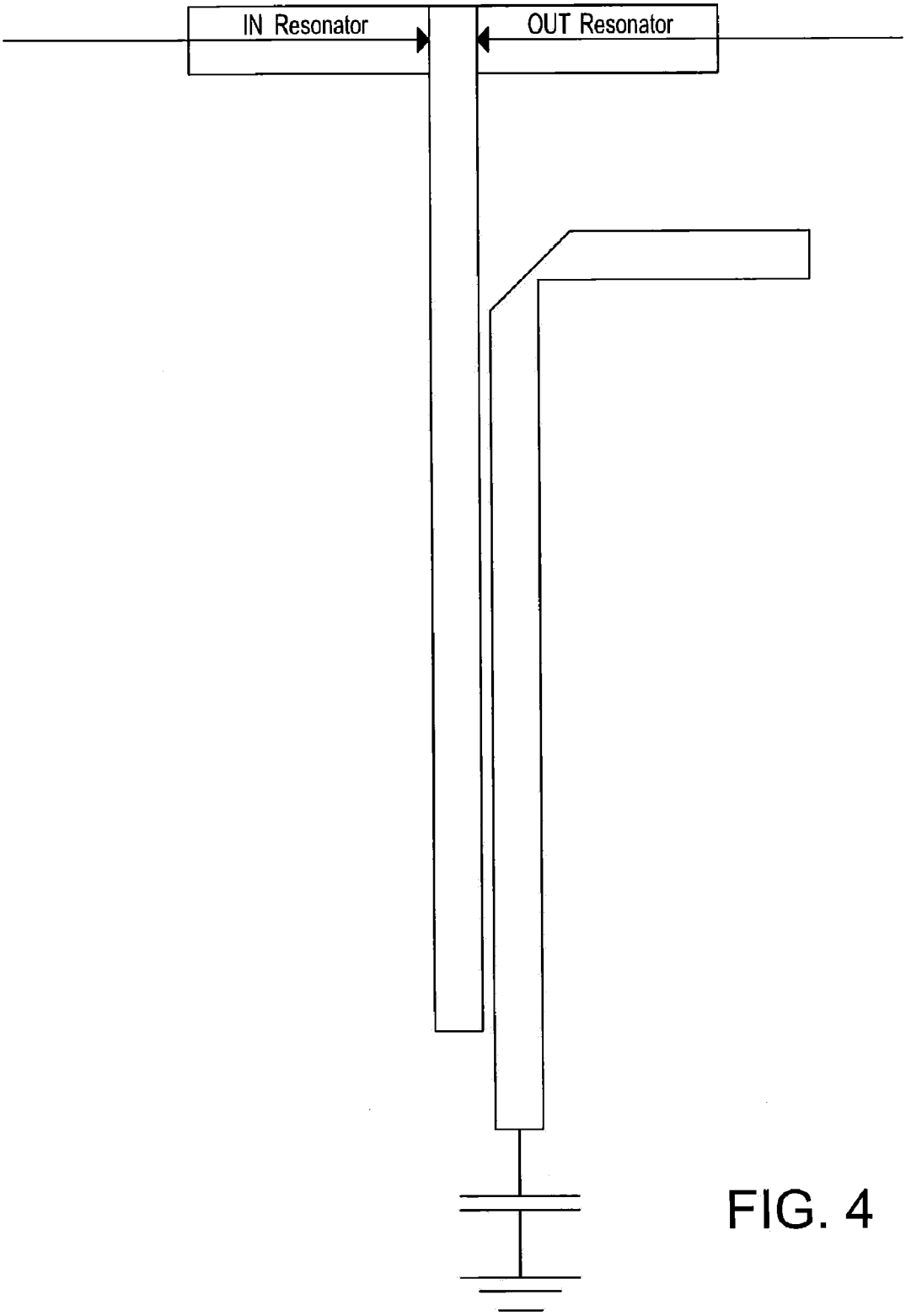

FIG. 4

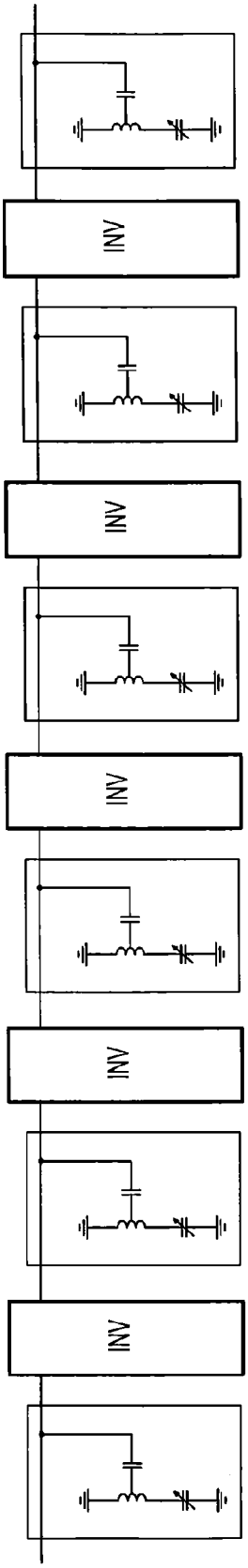

FIG. 5

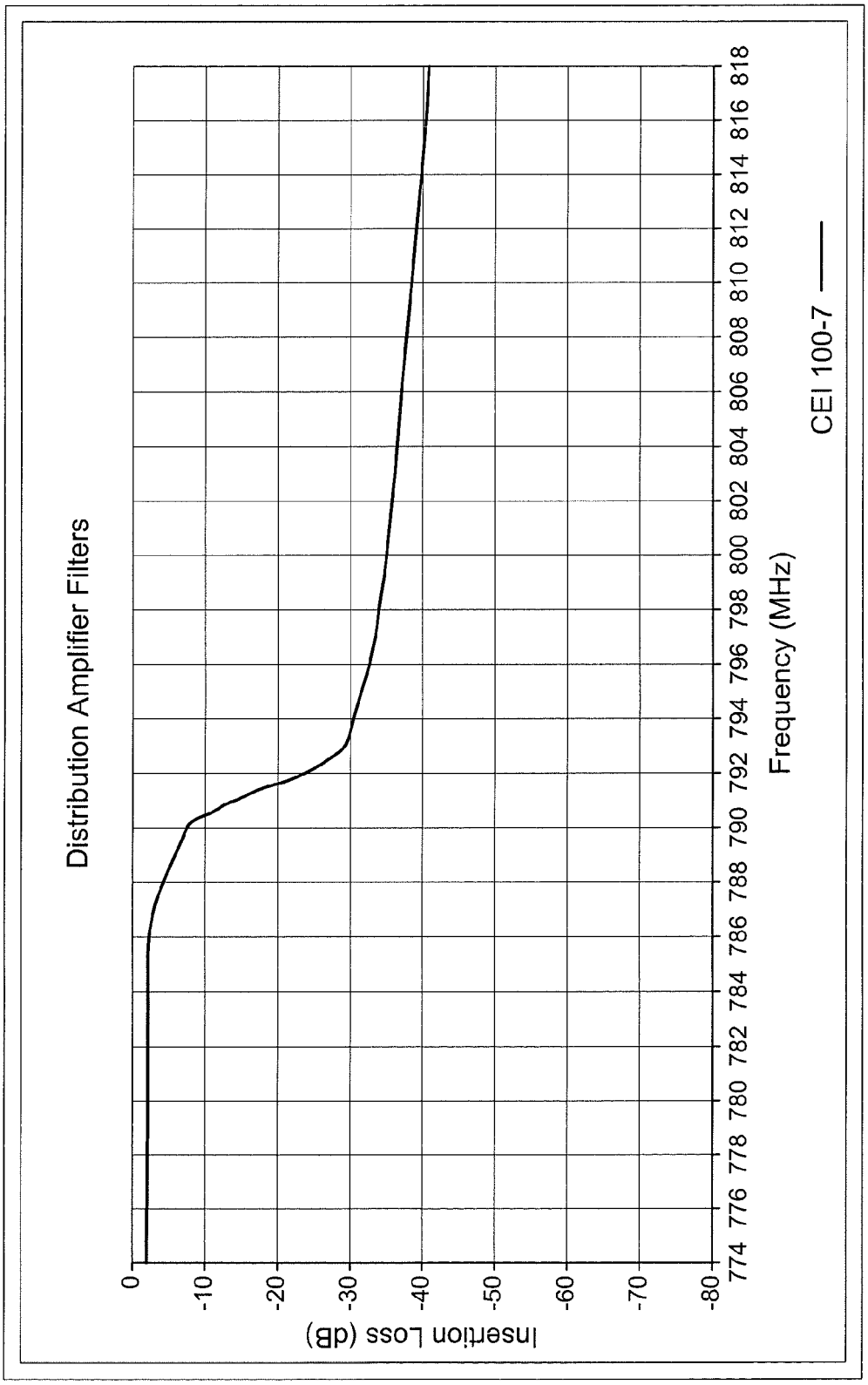

FIG.6

LTE curve CEI

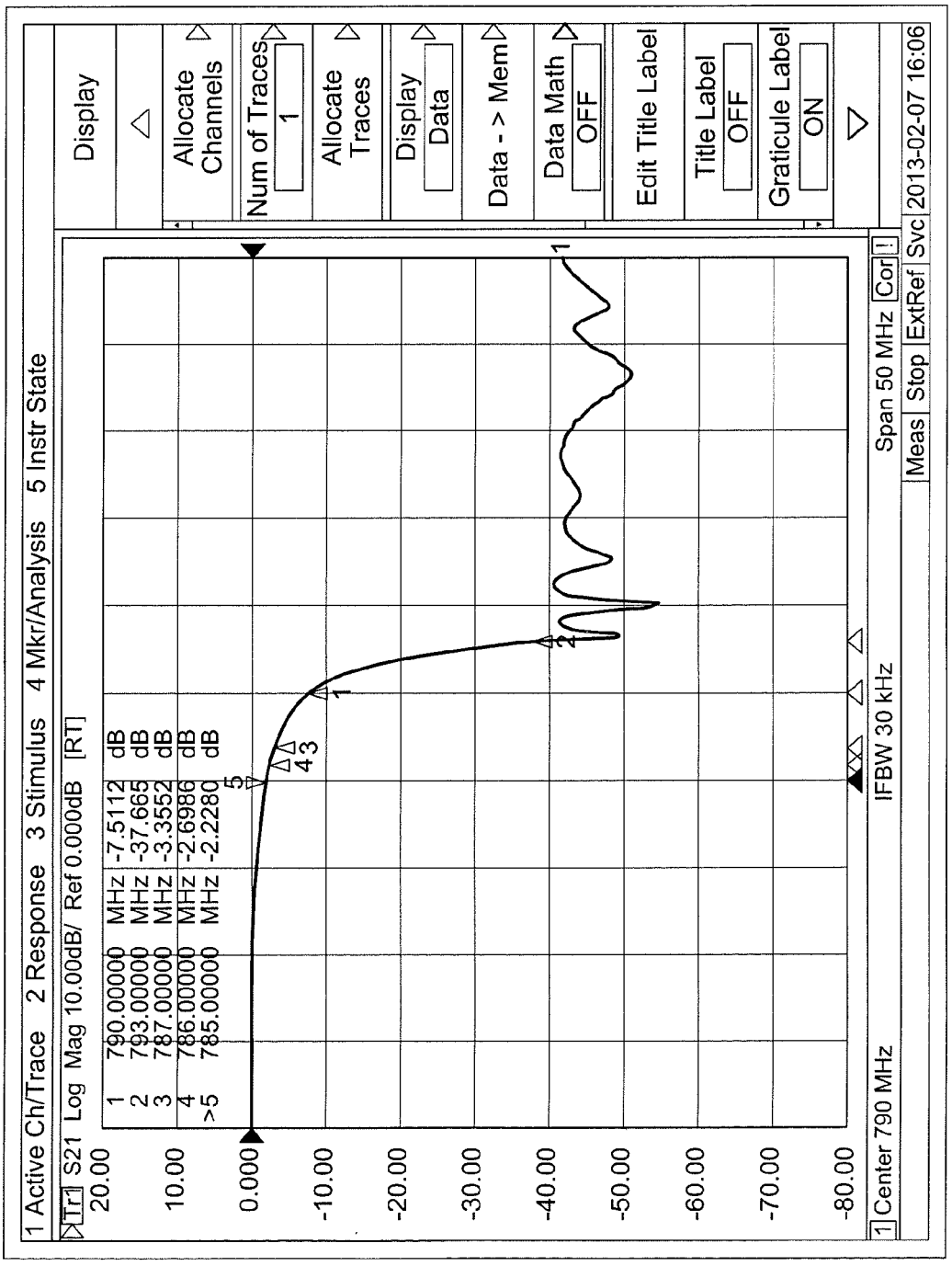

FIG.7

LTE curve 3B

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PARTIAL EUROPEAN SEARCH REPORT

under Rule 62a and/or 63 of the European Patent Convention. This report shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 13 16 0398

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2010/127801 A1 (ADKINS MICHAEL JOSEPH [US]) 27 May 2010 (2010-05-27) * figures 9,10 * * paragraph [0029] * -----	1-10	INV. H01P1/203
X	US 2006/273869 A1 (JACHOWSKI DOUGLAS R [US]) 7 December 2006 (2006-12-07) * paragraph [0167]; figures 25,26,38a,38b * -----	1-10	
X	EP 0 689 261 A1 (ALCATEL CABLE [FR]) 27 December 1995 (1995-12-27) * figure 3 * -----	1-10	
X	US 2010/265010 A1 (JIAN CHUN-YUN [CA]) 21 October 2010 (2010-10-21) * paragraph [0067]; figures 1-3 * -----	1-10	
X	US 2011/053622 A1 (MARUO TOMOHIKO [JP] ET AL) 3 March 2011 (2011-03-03) * paragraph [0031]; figure 1 * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

H01P
H03H

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

Place of search	Date of completion of the search	Examiner
The Hague	7 August 2013	Radomirescu, B-M

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 (P04E07)

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INCOMPLETE SEARCH
SHEET C

Application Number
EP 13 16 0398

Claim(s) completely searchable:
-

Claim(s) searched incompletely:
1-10

Reason for the limitation of the search:

Following the invitation pursuant to Rule 63(1) EPC the Applicant filed arguments, but also amendments to the original application.
As at the current stage of the proceedings there is no possibility of amending the application, the Examiner considered these amendments only as guidelines for deciding the extent of the search, and not for replacing the previous corresponding parts of the application.
1.
Claim 1 is unclear (Article 84 EPC), as it does not mention what is sought to be protected. The claim only states that "a structure of a low pass filter is designed ..." .
As it can be seen, despite claiming a structure, the claim defines the action of designing ("is designed") and not the result of this action - the filter structure.
2.
Even when reading the expression
"a structure of a low pass filter is designed ..."
as
"a structure of a low pass filter having ...",
claim 1 remains unclear, as it defines a cascade of two filters exclusively by desired properties or effects, contrary to the requirements of Article 84 EPC, because the "result-to-be-achieved" type of definition does not allow the scope of the claim to be ascertained.
Furthermore, the description does not provide support and disclosure within the meaning of Articles 84 and 83 EPC for all the filters having said desired properties or effects. It only provides support and disclosure for a reduced number of filters - see the embodiments - which renders the claimed scope not commensurate with the disclosed subject-matter.
The fact that any cascade structure of two filters could be tested does not overcome this objection, as the skilled person would not know beforehand whether it fell within the claimed scope, except for filters disclosed in the description. Undue experimentation would be required to test devices randomly.
Seen the above deficiencies, the clear assessment of the scope of the claim is virtually impossible and the search and examination of the claim could only be partially performed (Rule 63 EPC and Guidelines B-VIII, 3).
3.
Furthermore, claim 1 is unclear (Article 84 EPC), as the second filter is defined by what it can do, and not by what it comprises.
4.
Due to their dependency, claims 2-10 are also non-compliable with the above mentioned substantive provisions (Article 84 EPC).
5.
In particular, claims 2, 7 and 10 are unclear (Article 84 EPC), as they define only the nature of the parameters or constants of the low-pass filter, but not of the physical device. The claims define a filter, which

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INCOMPLETE SEARCH
SHEET C

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could have distributed parameters/constants (depending on the chosen model), yet having a lumped implementation.
6.
The expression "distributed with a matched coax" in claim 5 is not clear per se (Article 84 EPC).
7.
The term "bipolar inverter" in claim 8 is not clear per se (Article 84 EPC).
The Applicant submits on p. 4 of the letter of 02.08.2013 that:
"According to the invention, for making the series resonators of the circuit of Figure 1, an inventive circuit has been implemented, called in the Applicant's disclosure "inverter". More specifically, at a given frequency, such a line portion has a length corresponding to a fourth of a specific frequency wavelength and has a characteristic impedance which could be selected at any desired values or at 75 ohm."
The terms "bipolar inverter" and "inverter" (alone) do not have a clear, recognised meaning in the field.
The term needs to be defined by the its essential features.
8.
It is also not clear (Article 84 EPC) how a cascade connection of two stopband filters can result in an overall low pass filter. To recall, all the claims define such a combination.
9.
The Search Division considered it feasible to carry out a meaningful search only for the embodiments of the description, and only to the extent they are clear and sufficiently disclosed.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 16 0398

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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07-08-2013

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		US 2011053622 A1	03-03-2011

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82