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(54) **Filter assembly**

(57) A filter assembly is disclosed. The filter assembly is for filtering a radio frequency signal and comprises: a first filter having a first filter pass band and a first filter stop band, the first filter being operable to receive the radio frequency signal and to provide a first filtered radio frequency signal; a coupler operable to receive the first filtered radio frequency signal and to provide a second filtered radio frequency signal; and a pair of filtered reflective loads coupled with the hybrid coupler to receive the first filtered radio frequency signal and to provide the second filtered radio frequency signal, each filtered reflective load comprising a second filter and an impedance device, each second filter having a second filter pass band which overlaps with the first filter stop band. Selecting the pass-band of the filtered reflective loads to

overlap with the stop-band of the filter causes two effects. The first is that the portion of the filtered signal within the pass-band of the filtered reflective load is dissipated by the impedances, which provides a deep and broad transmission zero. It will be appreciated that by carefully arranging the position of the pass-bands and stop-bands of the filters, the position and breadth of the transmission zero can be controlled. Secondly, the radio frequency signal within the filtered signal in the pass-band of the filter will not be dissipated by the impedance device, but instead will be reflected back to the coupler to provide an output radio frequency signal. This means that high power does not flow through the filter within the filtered reflective loads and so smaller and less robust components can be used for that filter which reduces its size.

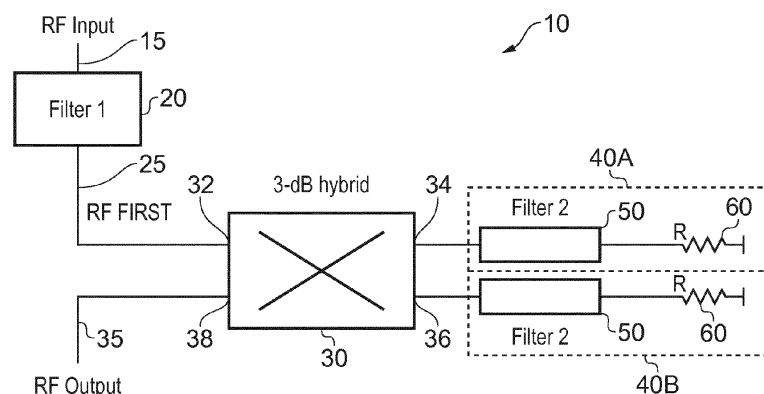


FIG. 1

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a filter assembly.

BACKGROUND

[0002] Filters or filter assemblies are widely used in telecommunications and, in particular, in wireless telecommunications systems. Their applications vary from use in base stations, radar systems, amplifier linearization, point-to-point radio systems, radio frequency signal cancellation and the like. The choice of a filter is ultimately dependent on the particular application. However, there are certain desirable characteristics that are typically common to all filters. For example, the amount of insertion loss in the pass-band of the filter should be as low as possible, while the attenuation in the stop-band of the filter should be as high as possible. Also, in some applications, the frequency separation between the pass-band and the stop-band (i.e., the guard band) needs to be very small which requires filters of high order to be deployed in order to achieve this requirement. However, the requirement for a high order filter typically results in an increase in the number of components that are required to implement the filter which leads to an increase in its physical size.

[0003] Accordingly, it is desired to provide an improved filter assembly.

SUMMARY

[0004] According to a first aspect, there is provided a filter assembly for filtering a radio frequency signal, the filter assembly comprising: a first filter having a first filter pass band and a first filter stop band, the first filter being operable to receive the radio frequency signal and to provide a first filtered radio frequency signal; a coupler operable to receive the first filtered radio frequency signal and to provide a second filtered radio frequency signal; and a pair of filtered reflective loads coupled with the coupler to receive the first filtered radio frequency signal and to provide the second filtered radio frequency signal, each filtered reflective load comprising a second filter and an impedance device, each second filter having a second filter pass band which overlaps with the first filter stop band.

[0005] The first aspect recognises that a problem with existing filters is their ability to enable the insertion of transmission zeros or notches into the response of the filter (i.e. portions within the response characteristic of the filter which provides a high degree of attenuation) so that rejection or attenuation is increased in order to achieve a high degree of isolation between, for example, transmit and receive channels. Although some filter architectures exist that provide for the insertion of such

transmission zeros, these are typically difficult and complex to reliably manufacture, they occupy a large amount of space, they provide relatively small transmission zeros and they have relatively high insertion losses.

[0006] Accordingly, a filter assembly is provided which may filter a radio frequency signal. The filter assembly may comprise a filter which receives a signal and provides a filtered signal. A coupler may be provided which receives the filtered signal and provides a filtered output signal. A pair of reflective loads may also be coupled with the coupler. Each reflective load may incorporate a filter and an impedance device. The filter of the reflective load may be configured to have a pass-band which overlaps with the stop-band of the filter which received the radio frequency signal.

[0007] In this way, the filter which receives the radio frequency signal and provides the filtered radio frequency signal highly attenuates that radio frequency signal in the stop-band regions of that filter (thus the power of the signal is greatly reduced in the stop-band regions) whilst the filtered signal is essentially unaffected in the pass-band region of the filter (thus the filtered signal is substantially at the full power of the radio frequency signal within the pass-band region) and this filtered signal is provided to the coupler. Selecting the pass-band of the filtered reflective loads to overlap with the stop-band of the filter causes two effects. The first is that the portion of the filtered signal within the pass-band of the filtered reflective load is dissipated by the impedances, which provides a deep and broad transmission zero. It will be appreciated that by carefully arranging the position of the pass-bands and stop-bands of the filters, the position and breadth of the transmission zero can be controlled. Secondly, the radio frequency signal within the filtered signal in the pass-band of the filter will not be dissipated by the impedance device, but instead will be reflected back to the coupler to provide an output radio frequency signal. This means that high power does not flow through the filter within the filtered reflective loads and so smaller and less robust components can be used for that filter which reduces its size.

[0008] In one embodiment, the second filter stop band overlaps with the first filter pass band. Accordingly, the stop-band of the second filter may be provided in the region of the pass-band of the first filter.

[0009] In one embodiment, each pass band comprises a region of low attenuation and each stop band comprises a region of high attenuation.

[0010] In one embodiment, the coupler is operable to receive the radio frequency signal at a first port, to provide the second filtered radio frequency signal at a second port, one of the pair of filtered reflective loads is coupled with a third port and another of the pair of filtered reflective loads is coupled with a fourth port. The first port may typically be designated as an input port, the second port may typically be designated as an output port, the third port may typically be designated as a direct port, and the fourth port may typically be designated as a coupled port.

An example of such a coupler is a 3-dB quadrature hybrid coupler.

[0011] In one embodiment, the coupler and the pair of filtered reflective loads comprise a filter network and the filter assembly comprises a plurality of the filter networks cascaded together in series. Accordingly, a cascade or series of couplers and reflective loads may be provided, each of which may sequentially add a further transmission zero to the response characteristics of the filter assembly. It will be appreciated that a cascaded arrangement is one in which the output of a previous coupler and reflective load arrangement feeds into the input of a subsequent coupler and reflective load arrangement. This leads to more sophisticated placement of transmission zeros.

[0012] In one embodiment, the filter assembly comprises: a second hybrid coupler operable to receive the second filtered radio frequency signal and to provide a third filtered radio frequency signal; and a second pair of filtered reflective loads coupled with the coupler to receive the second filtered radio frequency signal and to provide the third filtered radio frequency signal, each filtered reflective load comprising a third filter and an impedance device, each third filter having a third filter pass band which overlaps with the first filter stop band. Hence, two groups of coupler and filtered reflective loads may be arranged together.

[0013] In one embodiment, each filtered reflective load comprises the second filter and the impedance device coupled in parallel with a quarter wave phase shifter, a third filter and an impedance device. Providing a parallel arrangement of reflective loads at the respective ports of the hybrid coupler enables additional transmission zeros to be inserted into the response characteristic of the filter assembly without necessarily needing to cascade additional hybrid coupler and reflective load structures together. Instead, the parallel arrangement provides the same functionality as a cascaded arrangement with fewer components.

[0014] In one embodiment, the filter assembly comprises a quarter wave impedance transformer positioned at an input of each second and third filter. Providing such an impedance transformer compensates for the change in impedance presented to the hybrid coupler by the parallel arrangement of the reflective load.

[0015] In one embodiment, for a 50 ohm filter, each quarter wave impedance transformer has a characteristic impedance of around 70 ohms.

[0016] In one embodiment, the filter assembly comprises a quarter wave impedance transformer positioned between the coupler and each of the pair of filtered reflective loads. Similarly, this compensates for the change in impedance presented to the coupler by the parallel arrangement within the reflective load.

[0017] In one embodiment, for a 50 ohm filter, each quarter wave impedance transformer has a characteristic impedance of around 35 ohms.

[0018] In one embodiment, the second and third pass

bands match. Having pass-bands which are the same or which coincide ensures that the transmission zeros caused by the filtered reflective loads combine to increase the amount of attenuation and so deepen the transmission zeros.

[0019] In one embodiment, second and third pass bands overlap. By arranging for the pass-bands to overlap with each other adjacently, the width of the transmission zero can be extended across a wider range of frequencies.

[0020] In one embodiment, the second and third pass bands differ. By arranging for the pass-bands to differ, transmission zeros can be inserted in different locations within the filter characteristics. For example, the transmission zeros may be placed adjacent each other or in other locations in order to provide appropriate guard bands.

[0021] In one embodiment, the second pass band overlaps at a first end of the first filter stop band and the third pass band overlaps at a second end of the first filter stop band. Accordingly, transmission zeros may be placed on one side of the pass-band of the first filter and also on the other side of the pass-band of the first filter, thereby providing for a highly isolated and tightly restricted pass-band filter.

[0022] In one embodiment, the coupler comprises one of a hybrid coupler and a circulator.

[0023] Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

[0024] Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 illustrates a filter assembly according to one embodiment;

Figure 2 shows the attenuation characteristics of filters shown in Figure 1;

Figure 3 shows the attenuation characteristics the filter assembly shown in Figure 1;

Figure 4 shows the attenuation improvement in the stop-band when using the filter assembly shown in Figure 1;

Figure 5 illustrates a filter assembly according to one embodiment;

Figure 6 illustrates a filter assembly according to one embodiment;

Figure 7 shows the attenuation characteristics the filter and filter assembly shown in

Figure 1 and the filter assembly shown in Figure 6;

Figure 8 shows the attenuation improvement in the stop-band when using the filter assembly shown in Figure 1 and the filter assembly shown in Figure 6;

Figure 9A shows a basic configuration of a reflective type circuit;

Figure 9B shows a reflective load; and

Figure 9C shows another reflective load.

reflective loads, those filters can be smaller and have reduced power requirements.

[0028] By carefully selecting the relationship between the pass-bands and stop-bands of the filters, the location of the transmission zero can be easily adjusted. Also, by either augmenting the reflective loads or by adding further sets of hybrid couplers and reflective loads having different filter characteristics, additional transmission zeros can be introduced at different points in the response characteristics and/or broaden the transmission zeros.

DESCRIPTION OF THE EMBODIMENTS

Overview

[0026] Before discussing embodiments in any more detail, first an overview will be provided. As mentioned above, filters are widely used in telecommunications. Such filters typically require that the amount of insertion loss in the pass-band of the filter should be as low as possible, while the attenuation in the stop-band should be as high as possible. The requirement for high attenuation in the stop-band is driven by the increasing requirements for higher isolation between transmission and reception channels in wireless telecommunications systems. Accordingly, embodiments are provided which provide for the insertion of at least one transmission zero (a notch or region of high attenuation) in the response of the filter. Such transmission zeros are normally introduced in the stop-band of the filter so that the rejection (or attenuation) is increased.

[0027] Accordingly, embodiments provide a filter architecture which provides for an arrangement which is compact, simple to manufacture, enables the reliable placement of transmission zeros and minimises insertion losses. The filter architecture utilises a first, primary or initial filter which receives a radio frequency (RF) signal and provides a filtered signal to a hybrid coupler (such as a 3-dB quadrature hybrid coupler). A pair of identical filtered reflective loads is provided, each one of which is coupled with a respective port of the hybrid coupler. The resultant filtered signal is then provided at a fourth port of the hybrid coupler as an output signal. By selecting the first filter and the filters in the filtered reflective load to have their pass-bands and stop-bands in specific locations, one or more transmission zeros may be introduced. In particular, by arranging the pass-band of the filters in the reflective loads to be in the vicinity of the stop-band of the first filter, any RF signal within the stop-band of the first filter may pass through the filter of the reflective loads and be dissipated by an impedance of the reflective loads. Also, any signal which is within the pass-band of the first filter will not pass through the filter of the reflective loads and be dissipated by the impedance of the reflective loads, but will instead be reflected back to the output port. This approach enables a relatively broad transmission zero to be introduced and, because high RF power does not flow into the filter of the filtered

Broad Transmission Zero Filter

[0029] Figure 1 illustrates a broad zero filter assembly, generally 10, according to one embodiment. A signal RF_{input} to be filtered is provided over an input path 15 to a first filter 20. An output path 25 from the first filter 20 provides a filtered signal RF_{first} to an input port 32 of a 3-dB hybrid coupler 30. Coupled with the 3-dB hybrid coupler 30 is a pair of identical filtered loads 40A, 40B, each of which comprise a second filter 50 arranged in series with a resistor 60. Each of the filtered reflective loads 40A, 40B is coupled with a respective port 34, 36 of the 3-dB hybrid coupler 30. An output signal RF_{output} is provided over the path 35 from a fourth port 38 of the 3-dB hybrid coupler 30.

[0030] As can be seen in Figure 2, the first filter 20 and the second filter 50 have their pass-bands in the vicinity of each other. In particular, the stop-band of the first filter 20 overlaps with the pass-band of the second filter 50. This means that the RF signal existing in the stop-band of the first filter 20 which coincides with the pass-band of the second filter will have its power dissipated by the resistors 60. Also, one of the stop-bands of the second filter 50 coincides with the pass-band of the first filter 20. Given the operation of the 3-dB coupler 30, this means that the RF signal in the pass-band of the first filter 20 will not have its power dissipated by the resistors 60 but, instead, will be reflected back to the output port 38. Accordingly, the high RF power which passes through the first filter 20 does not flow through the second filters 50 and so smaller and less robust components can be used to make the second filter 50.

[0031] As can be seen in Figure 3, this introduces a broad and significant transmission zero into the response of the filter assembly 10 compared to the response of the first filter 20 alone.

[0032] As can be seen in Figure 4, which shows the attenuation improvement in the stop-band when using the filter assembly 10 shown in Figure 1 compared to the performance obtained by using the first filter 20 alone, the transmission zero obtained by the filter assembly 10 is broad and has improved the stop-band performance significantly, at least by 16dB in the stop-band region of 2.52 to 2.57 GHz.

[0033] In order to generate these response characteristics, real-world filters have been used in these simulations (i.e., their respective two-port scattering parameters

have been used) and the first filter 20 is a four pole filter designed in-house whilst the second filter 50 is an off-the-shelf component from CTS (CER0753B).

[0034] A downside of this arrangement is that the improvement in the performance of the stop-band has a consequence of a small deterioration in the insertion loss in the pass-band. In particular, the insertion loss in the pass-band is increased by 0.4 dB compared to the insertion loss exhibited by the first filter 20 alone. However, the improvement in the stop-band is typically enough to justify this additional attenuation.

[0035] In order to improve attenuation performance, additional transmission zeros may be introduced, as set out in the embodiments described below.

Cascaded Filter

[0036] As shown in Figure 5, a cascaded arrangement of filter assembly, generally 10a, is provided in order to introduce further transmission zeros into the response characteristic of the filter assembly 10a. The filter assembly 10a comprises the same arrangement as the filter 10 mentioned above, but the signal provided over the path 35 is then fed into another 3-dB hybrid coupler 30a and filtered reflective load 40c, 40d arrangement. This enables additional transmission zeros to be inserted, depending on the stop-band and pass-band characteristics of the second filters 50a. The output signal RF_{output} is then provided over the path 45 from the output port of the 3-dB hybrid coupler 30a.

[0037] If the response characteristics of the second filters 50a are identical to that of the second filters 50, then the transmission zeros will align and greater attenuation will occur in the same region as that shown in Figure 3 for the arrangement shown in Figure 1. However, the second filters 50a response characteristics need not be identical to the second filters 50. For example, the pass-band of the second filters 50a may be offset but overlap with the pass-band of the second filters 50 in order to broaden the transmission zero (i.e., increase the range of frequencies at which high attenuation occurs); for example, the pass-band of the second filter 50a may be set to be in the region of around 2.4 to 2.5 GHz. In addition, the second filters 50a may have their pass-bands overlapping the other stop-band of the first filter 20; for example, the pass-band of the second filter 50a may be set to be in the region of around 2.7 to 2.8 GHz.

[0038] It will be appreciated that further cascaded arrangements of 3-dB hybrid couplers and filtered reflective loads may be provided in order to introduce further transmission zeros.

[0039] Although this arrangement facilitates the introduction of further transmission zeros, it increases the complexity, the number of components needed and ultimately increases the space occupied on, for example, a printed circuit board. Accordingly, a similar effect can be achieved which improves the attenuation in the stop-band by adding further transmission zeros but which also

reduces complexity, the number of components needed and the space occupied on the printed circuit board, as will now be discussed below.

5 Simplified Cascaded Filter

[0040] Figure 6 illustrates a filter assembly, generally 10b, according to one embodiment. This embodiment utilises the filter assembly arrangement of Figure 1 mentioned above. However, additional reflective loads 40e, 40f are provided. The additional reflective load 40e is provided in parallel with the reflective load 40a at the direct port 34 of the 3-dB hybrid coupler 30. The reflective load 40f is provided in parallel with the reflective load 40b at the coupled port 36 of the 3-dB hybrid coupler 30. The reflective loads 40e, 40f are identical to the reflective loads 40c, 40d mentioned above, with the addition of a 90° phase shifter 70a which precedes the second filter 50a and the resistor 60a. The 90° phase shifter 70a can be implemented using a simple quarter wave transformer. The provision of the 90° phase shifter 70a ensures that an additional transmission zero is inserted into the response characteristics of the filter assembly 10b.

[0041] Again, if the response characteristics of the second filters 50a are identical to that of the second filters 50, then the transmission zeros will align and greater attenuation will occur in the same region as that shown in Figure 3 for the arrangement shown in Figure 1. However, the second filters 50a response characteristics need not be identical to the second filters 50. For example, the pass-band of the second filters 50a may be offset but overlap with the pass-band of the second filters 50 in order to broaden the transmission zero (i.e., increase the range of frequencies at which high attenuation occurs); for example, the pass-band of the second filter 50a may be set to be in the region of around 2.4 to 2.5 GHz. In addition, the second filters 50a may have their pass-bands overlapping the other stop-band of the first filter 20; for example, the pass-band of the second filter 50a may be set to be in the region of around 2.7 to 2.8 GHz. However, care is needed to ensure that the selection of the arrangement of the reflective loads 40e, 40f satisfies equations (1) to (6) mentioned below.

[0042] Given that the arrangement shown in Figure 6 presents two, typically 50Ω, loads connected in parallel at both the direct port 34 and the coupled port 36, the reference impedance of the 3 dB hybrid coupler would need to be 25Ω. However, this can be avoided by either introducing a 70.7Ω three quarter wave impedance transformer prior to each of the second filters 50, 50a or by introducing a 35-35Ω quarter wave impedance transformer between the direct port 34 and the parallel arrangement of the reflective loads 40a and 40e, and between the coupled port 36 and the parallel arrangement of the reflective load 40b and the reflective load 40f.

[0043] Figure 7 shows the attenuation achieved by the first filter 20, the filter assembly 10 of Figure 1 and the filter assembly 10b of Figure 6 when utilising the 70.7Ω

quarter wave impedance transformers prior to the second filters 50, 50a mentioned above. As can be seen, the stop-band attenuation has been greatly increased by the filter assembly 10b and its attenuation is at least 18 dB greater than the attenuation provided by the filter assembly 10.

[0044] Figure 8 illustrates the improvement of the stop-band performance using the filter assembly 10 and filter assembly 10b with reference to the response of the first filter 20. As can be seen, improvements of around 40 dB are recorded in the frequency band 2.52 to 2.57 GHz using the filter assembly 10b shown in Figure 6, which can be compared to an improvement of over 16 dB obtained using the filter 10 assembly of Figure 1.

[0045] However, it will be appreciated that this improvement is not obtained without some sacrifices, as the insertion loss in the pass-band has increased by up to 0.4 dB compared to the insertion loss obtained by the filter assembly 10 shown in Figure 2. However, such a sacrifice is generally acceptable in most applications, especially in view of the improvements in attenuation in the stop band.

[0046] The following sets out the reasoning why additional (double) zeros occur in the arrangement shown in Figure 6 above, which leads to increased rejection.

[0047] Figure 9a shows a basic configuration of a reflective type circuit.

[0048] The reflective loads, Γ_1 and Γ_2 are assumed to be the same, $\Gamma_1 = \Gamma_2 = \Gamma$, and the loads take the form given in Figure 9b.

[0049] The transmission coefficient of the reflective circuit of Fig.9a is now:

$$S_{21} = -j\Gamma = -j \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \quad (1)$$

[0050] The transmission zero is introduced when $S_{21} = 0$, i.e. when $Z_{in} = Z_0 = 50\Omega$. This is a single transmission zero, introduced by the reflective circuit.

[0051] For the more complicated reflective load shown in Figure 9C, the expression for the transmission coefficient is:

$$S_{21} = -j\Gamma = j \frac{-Z_2 Z_{02}^2 + Z_0 Z_{01}^2 + Z_0 Z_1 Z_2}{Z_2 Z_{02}^2 + Z_0 Z_{01}^2 + Z_0 Z_1 Z_2} \quad (2)$$

[0052] Under the assumption $Z_1 = Z_2 = Z$, (2) becomes:

$$S_{21} = -j\Gamma = j \frac{-ZZ_{02}^2 + Z_0 Z_{01}^2 + Z_0 Z^2}{ZZ_{02}^2 + Z_0 Z_{01}^2 + Z_0 Z^2} \quad (3)$$

[0053] The transmission zero is now found from $S_{21} = 0$, i.e.:

$$Z_{1,2} = \frac{Z_{02}^2 \pm \sqrt{Z_{02}^4 - 4Z_0^2 Z_{01}^2}}{2Z_0} \quad (4)$$

[0054] The condition that the discriminant disappears yields a double zero at:

$$Z_{1,2} = \frac{Z_{02}^2}{2Z_0} \quad (5)$$

[0055] While the condition for zero discriminant is obtained from $Z_{02}^4 - 4Z_0^2 Z_{01}^2 = 0$ to yield:

$$Z_0^2 = \frac{Z_{02}^4}{4Z_{01}^2} \quad (6)$$

[0056] Condition (6) is needed and necessary to obtain the relationship between the termination impedance of the coupler and the impedance transformers, Z_{01} and Z_{02} in order to achieve a double zero. If, however, a double zero is not required, the discriminant in (4) need not to be set to zero, but with a careful choice of the characteristic impedances, Z_{01} and Z_{02} the two zeros can be set further apart from each other.

[0057] Example for a double zero: For $Z_0 = 50\Omega$ and $Z_{02} = 70.7\Omega$ (6) yields $Z_{01} = 50\Omega$. At the same time (5) yields a double zero at $Z_{1,2} = 50\Omega$.

[0058] From (2), it further follows that if the filters are dissimilar, i.e. $Z_1 \neq Z_2$, a double zero can still be achieved, however, that would require a different choice of characteristics impedances, Z_{01} and Z_{02} .

[0059] Accordingly, embodiments provide an elegant architecture for achieving deeper and/or multiple transmission zeros in the response characteristics of a filter.

[0060] Although embodiments mentioned above utilise a hybrid coupler, other couplers such as a circulator may be utilised.

[0061] A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

[0062] The functions of the various elements shown in the Figures, including any functional blocks labelled as "processors" or "logic", may be provided through the use

of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" or "logic" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the Figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0063] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0064] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Claims

1. A filter assembly for filtering a radio frequency signal, said filter assembly comprising:

a first filter having a first filter pass band and a first filter stop band, said first filter being operable to receive said radio frequency signal and to

provide a first filtered radio frequency signal; a coupler operable to receive said first filtered radio frequency signal and to provide a second filtered radio frequency signal; and a pair of filtered reflective loads coupled with said coupler to receive said first filtered radio frequency signal and to provide said second filtered radio frequency signal, each filtered reflective load comprising a second filter and an impedance device, each second filter having a second filter pass band which overlaps with said first filter stop band.

2. The filter assembly of claim 1, wherein said second filter stop band overlaps with said first filter pass band.
3. The filter assembly of claim 1 or 2, wherein each pass band comprises a region of low attenuation and each stop band comprises a region of high attenuation.

4. The filter assembly of any preceding claim, wherein said coupler is operable to receive said radio frequency signal at a first port, to provide said second filtered radio frequency signal at a second port, one of said pair of filtered reflective loads is coupled with a third port and another of said pair of filtered reflective loads is coupled with a fourth port.

5. The filter assembly of any preceding claim, wherein said coupler and said pair of filtered reflective loads comprise a filter network and said filter assembly comprises a plurality of said filter networks cascaded together in series.

6. The filter assembly of any preceding claim, comprising:

a second coupler operable to receive said second filtered radio frequency signal and to provide a third filtered radio frequency signal; and a second pair of filtered reflective loads coupled with said coupler to receive said second filtered radio frequency signal and to provide said third filtered radio frequency signal, each filtered reflective load comprising a third filter and an impedance device, each third filter having a third filter pass band which overlaps with said first filter stop band.

7. The filter assembly of any preceding claim, wherein each filtered reflective load comprises said second filter and said impedance device coupled in parallel with a quarter wave phase shifter, a third filter and an impedance device.

8. The filter assembly of claim 7, comprising a quarter

wave impedance transformer positioned at an input of each second and third filter.

9. The filter assembly of claim 8, wherein for a 50 ohm filter, each quarter wave impedance transformer has a characteristic impedance of around 70 ohms. 5
10. The filter assembly of claim 7, comprising a quarter wave impedance transformer positioned between said hybrid coupler and each of said pair of filtered reflective loads. 10
11. The filter assembly of claim 10, wherein for a 50 ohm filter, each quarter wave impedance transformer has a characteristic impedance of around 35 ohms. 15
12. The filter assembly of any one of claims 7 to 11, wherein said second and third pass bands match.
13. The filter assembly of any one of claims 7 to 11, wherein said second and third pass bands differ. 20
14. The filter assembly of any one of claims 7 to 13, wherein said second and third pass bands overlap. 25
15. The filter assembly of any one of claims 7 to 14, wherein said second pass band overlaps at a first end of said first filter stop band and said third pass band overlaps at a second end of said first filter stop band. 30

Amended claims in accordance with Rule 137(2) EPC.

1. A filter assembly (10B) for filtering a radio frequency signal (RF INPUT), said filter assembly comprising: 35
 - a first filter (20) having a first filter pass band and a first filter stop band, said first filter being operable to receive said radio frequency signal and to provide a first filtered radio frequency signal (RF FIRST); 40
 - a coupler (30) operable to receive said first filtered radio frequency signal and to provide a second filtered radio frequency signal (RF OUTPUT); and 45
 - a pair of filtered reflective loads (40A; 40B) coupled with said coupler to receive said first filtered radio frequency signal and to provide said second filtered radio frequency signal, each filtered reflective load comprising a second filter (50) and an impedance device (60), each second filter having a second filter pass band which overlaps with said first filter stop band, wherein each filtered reflective load comprises said second filter and said impedance device coupled in par- 50

allel with a quarter wave phase shifter (70A), a third filter (50A) and an impedance device (60A).

2. The filter assembly of claim 1, wherein said second filter stop band overlaps with said first filter pass band.
3. The filter assembly of claim 1 or 2, wherein each pass band comprises a region of low attenuation and each stop band comprises a region of high attenuation.
4. The filter assembly of any preceding claim, wherein said coupler is operable to receive said radio frequency signal at a first port (32), to provide said second filtered radio frequency signal at a second port (38), one of said pair of filtered reflective loads is coupled with a third port (34; 36) and another of said pair of filtered reflective loads is coupled with a fourth port (36; 34).
5. The filter assembly of any preceding claim, wherein said coupler and said pair of filtered reflective loads comprise a filter network and said filter assembly comprises a plurality of said filter networks cascaded together in series.
6. The filter assembly of any preceding claim, comprising:
 - a second coupler operable to receive said second filtered radio frequency signal and to provide a third filtered radio frequency signal; and
 - a second pair of filtered reflective loads coupled with said coupler to receive said second filtered radio frequency signal and to provide said third filtered radio frequency signal, each filtered reflective load comprising a third filter and an impedance device, each third filter having a third filter pass band which overlaps with said first filter stop band.
7. The filter assembly of claim 1, comprising a quarter wave impedance transformer positioned at an input of each second and third filter.
8. The filter assembly of claim 7, wherein for a 50 ohm filter, each quarter wave impedance transformer has a characteristic impedance of around 70 ohms.
9. The filter assembly of claim 1, comprising a quarter wave impedance transformer positioned between said hybrid coupler and each of said pair of filtered reflective loads.
10. The filter assembly of claim 9, wherein for a 50 ohm filter, each quarter wave impedance transform-

er has a characteristic impedance of around 35 ohms.

11. The filter assembly of any one of claims 1 to 10, wherein said second and third pass bands match. 5

12. The filter assembly of any one of claims 1 to 10, wherein said second and third pass bands differ.

13. The filter assembly of any one of claims 1 to 12, wherein said second and third pass bands overlap. 10

14. The filter assembly of any one of claims 1 to 13, wherein said second pass band overlaps at a first end of said first filter stop band and said third pass band overlaps at a second end of said first filter stop band. 15

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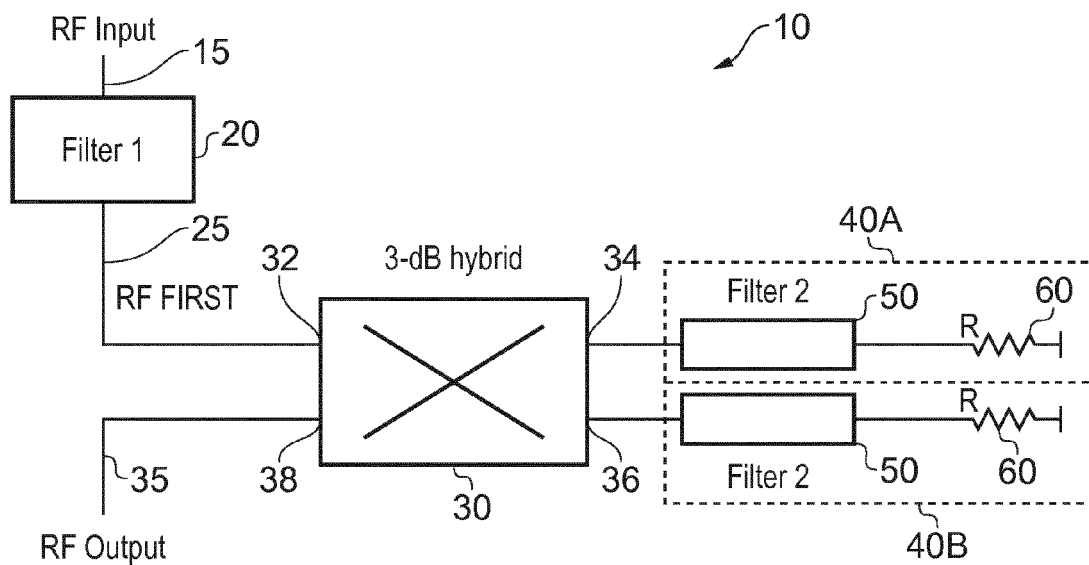


FIG. 1

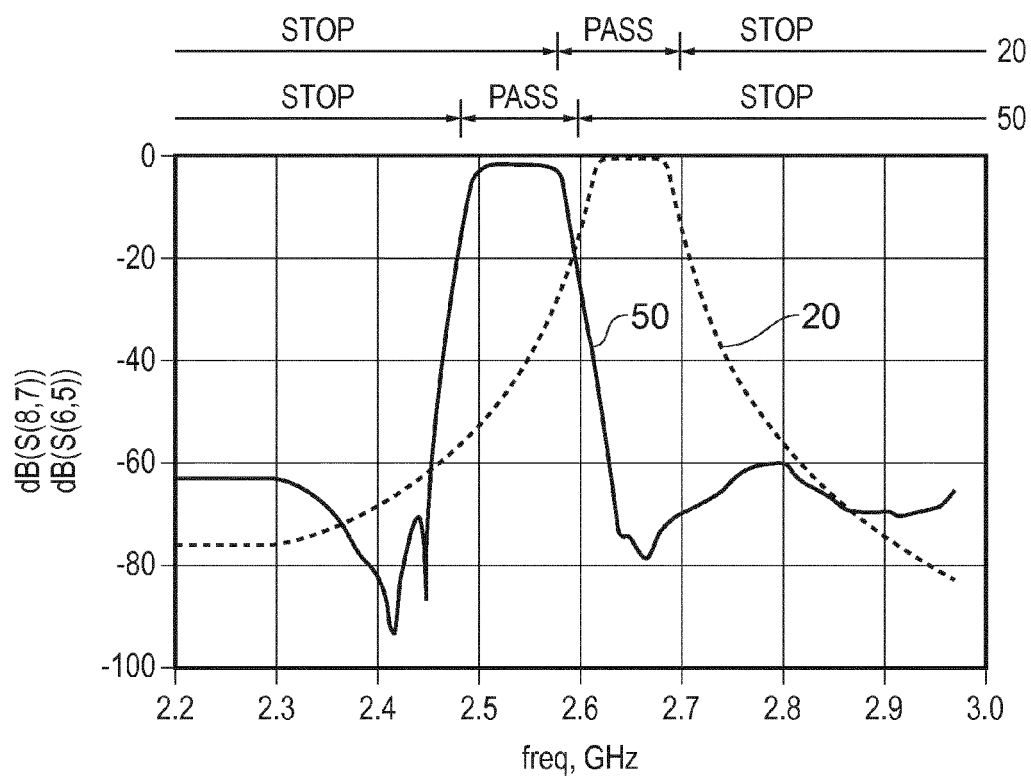


FIG. 2

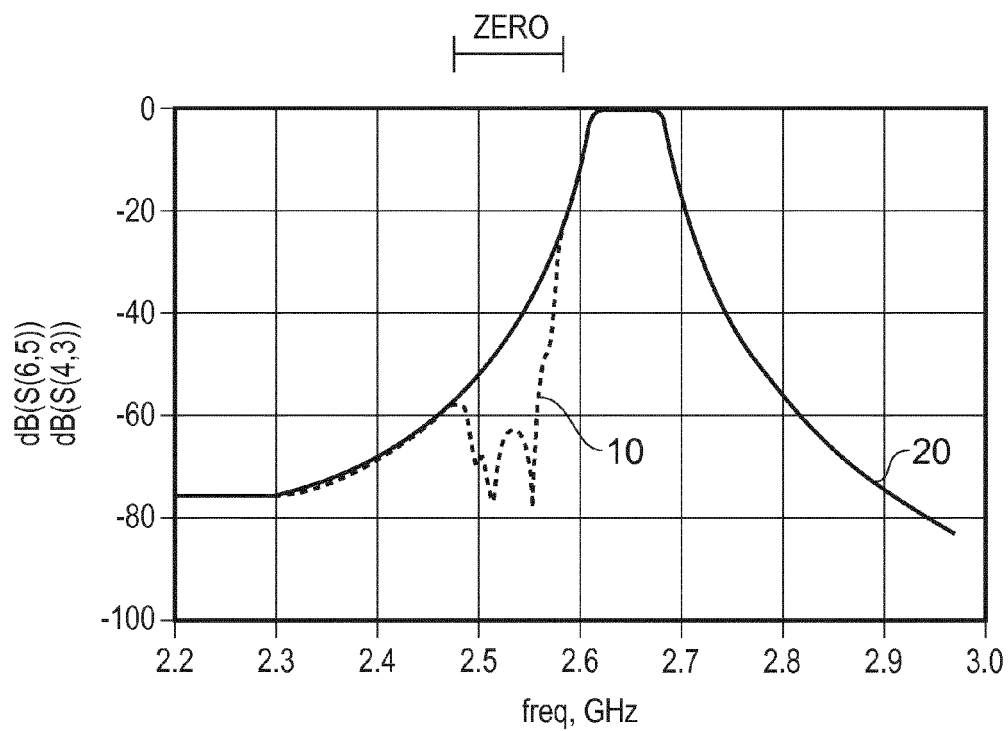


FIG. 3

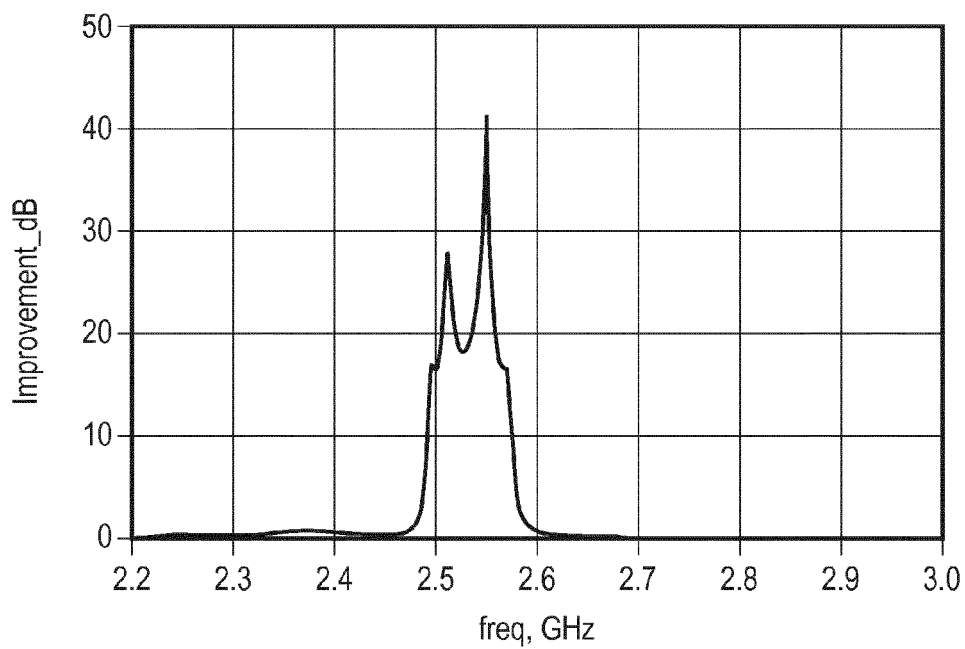


FIG. 4

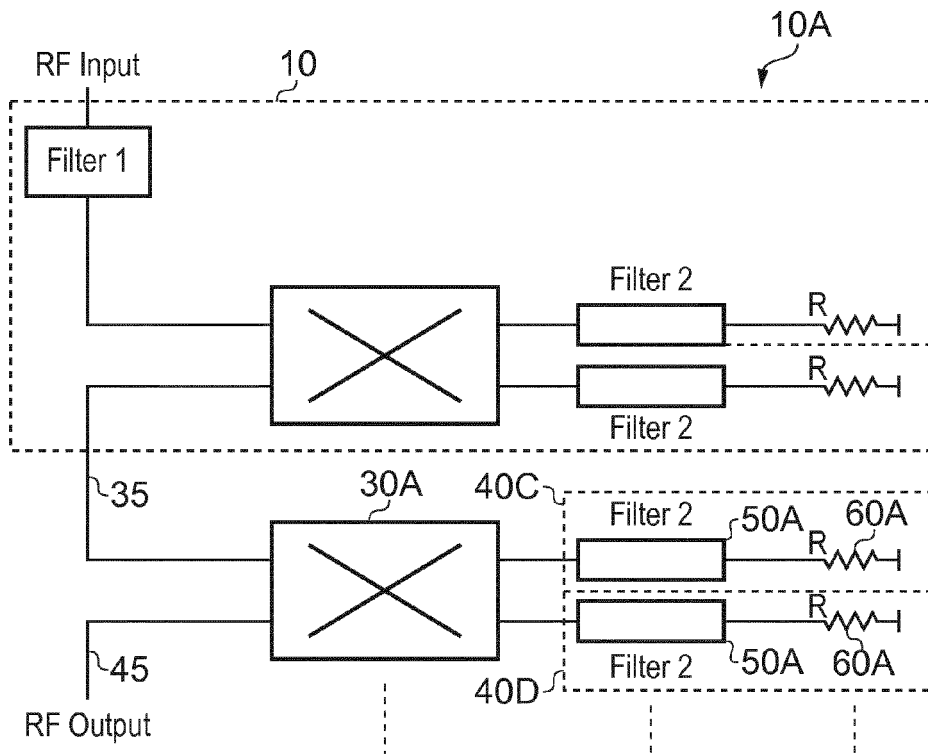


FIG. 5

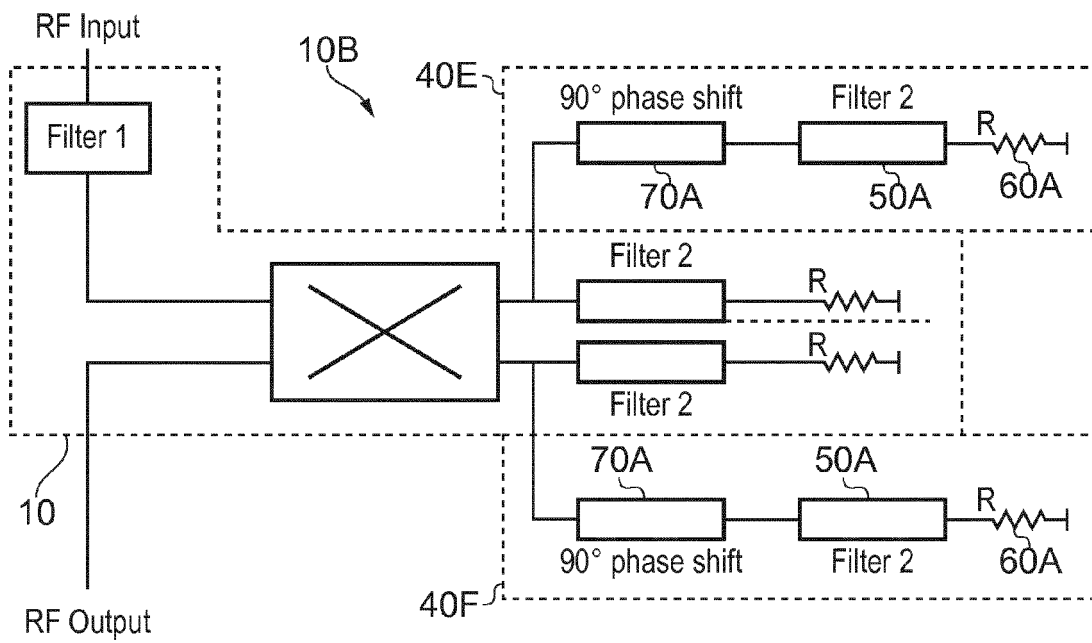


FIG. 6

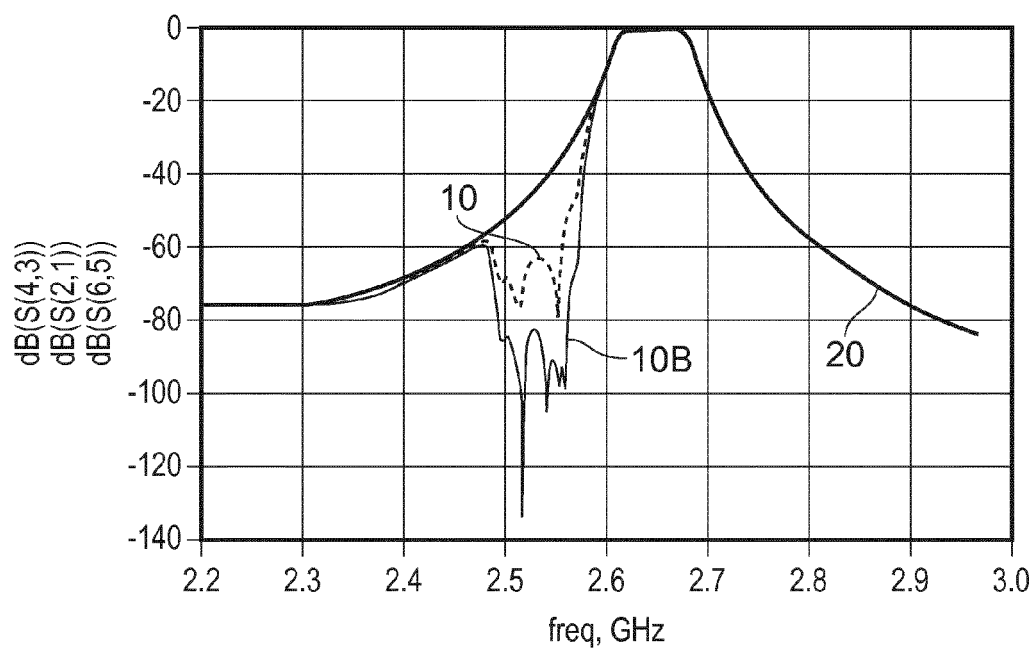


FIG. 7

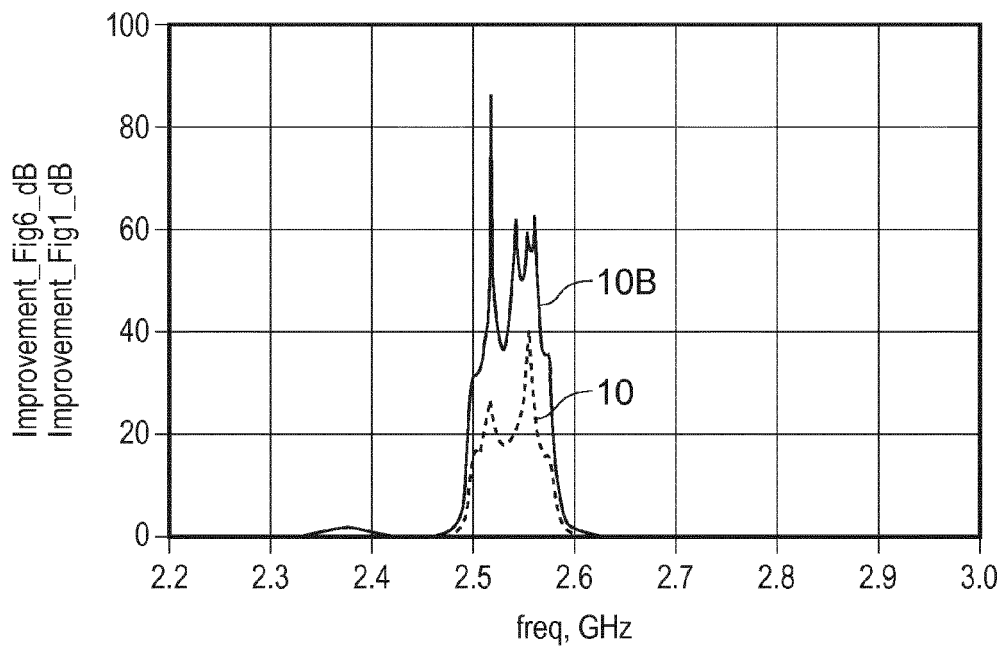


FIG. 8

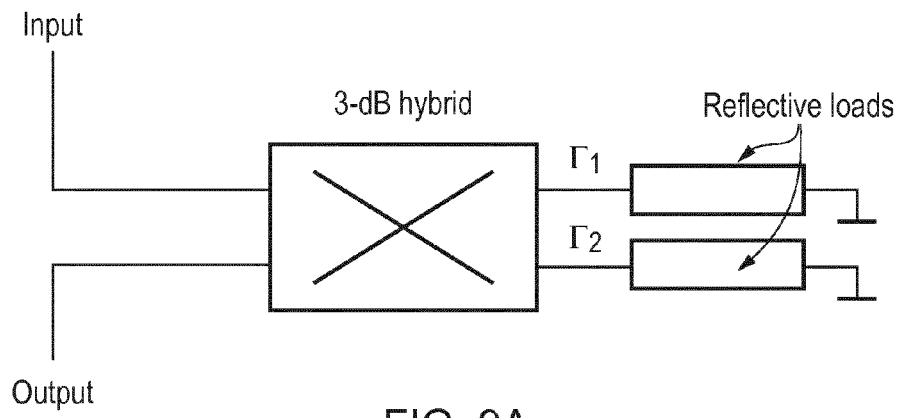


FIG. 9A

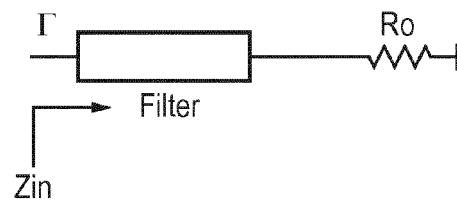


FIG. 9B

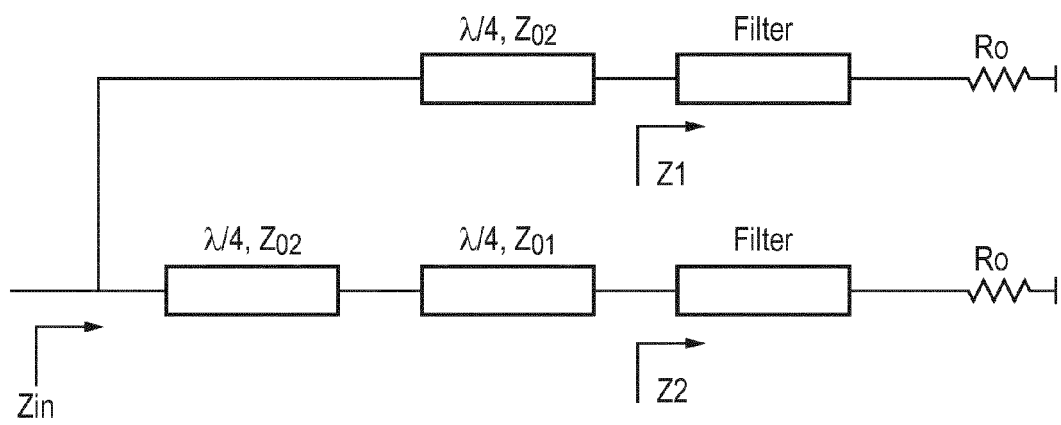


FIG. 9C



EUROPEAN SEARCH REPORT

Application Number
EP 12 36 0054

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 2011/080856 A1 (KENINGTON PETER [GB]) 7 April 2011 (2011-04-07) * abstract * * paragraphs [0042], [0044] - [0047]; figures 3a,4,5,6 * -----	1-6	INV. H01P1/20
A	JP 2007 208350 A (NIPPON DENGYO KOSAKU CO LTD; JAPAN BROADCASTING CORP) 16 August 2007 (2007-08-16) * abstract; figures 4,9-11 * -----	6	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01P
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 7 December 2012	Examiner Jäschke, Holger
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			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 12 36 0054

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The members are as contained in the European Patent Office EDP file on
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07-12-2012

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