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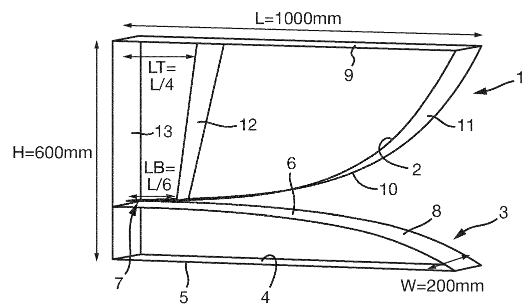
(54) WIDE BAND ANTENNA

(57) A method of manufacturing an antenna element having an upper loop (1)and a lower loop (3), said upper loop (1) comprising a first conductive loop element (2) defined by an upper conductor (9) and a first conductive blade member (10) that tapers outwardly to form a flare portion (11) adjacent a distal end of said upper conductor (9), said lower loop (3) comprising a second conductive loop element (4) defined by a base conductor (5) and a second conductive blade member (6) that tapers outwardly to form a flare portion (8) adjacent a distal end of said base conductor (5), said first and second conductive blade members (10, 6) defining, between their facing edges, a notch which opens outwardly from a feed region (7), said upper loop (1) further comprising an elongate conductive vane (12) extending at an angle from a first location on said upper conductor (9) to a second location on said first conductive blade (10) to define a pair of loops within said upper loop (1), the method comprising:
selecting a desired operating frequency range;
matching, at said desired operating frequency range an impedance of said antenna element to a transmission line to be connected at said feed region (7) thereof;
selecting a predetermined performance characteristic of said antenna element; and:
selecting a minimum distance of said second location from said feed region (7) at which said impedance match is maintained and said performance characteristic is attained, and placing said conductive vane (12) within said upper loop (1) such that it extends from said selected second location on said first conductive blade (10) to a first location on said upper conductor (9); and/or
selecting an angle of inclination of said conductive vane (12) within said upper loop (1) at which said performance characteristic is attained, and placing said conductive vane (12) at said selected angle of inclination between said first location on said upper conductor (9) and said second location on said first conductive blade (10).

Fig. 2



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Description

[0001] This invention relates, in a first aspect, to a method of manufacturing an antenna element; in a second aspect to an antenna element; and in a third aspect to a wide band antenna comprising an array of antenna elements.

[0002] Wide band technology is increasingly being developed for communications and other applications. Unlike narrow band systems, which operate at specific frequencies, wide band systems can transmit and receive sequences of very short pulses, i.e. pulses generated from a broad range or bandwidth of frequencies (typically several MHz to several GHz) of the electromagnetic spectrum. The input to a wide band antenna is typically from one or more pulsed sources, and the antenna is required to radiate incident energy into free space.

[0003] Clearly, optimising performance is a key consideration in antenna design. Regardless of the type and configuration of an antenna, its performance can be characterised by (at least) the following metrics:

i) Impedance bandwidth

ii) Directive Gain

iii) Efficiency

[0004] Antenna impedance, and the radio frequencies over which that impedance is maintained, are critical. It is essential that the antenna present an acceptable impedance match over the frequency band(s) of operation. Antenna impedance and the quality of the impedance match are most commonly characterized by either return loss (represented by the scattering parameter S11) or Voltage Standing Wave Ratio (VSWR) - these two parameters are simply different formats of exactly the same impedance data. S11 or return loss, then, is a measure of how much power is reflected back at the antenna port due to mismatch from the transmission line.

[0005] Bandwidth refers to the range of frequencies a given return loss can be maintained. Since return loss is a measurement of how much power the antenna accepts from the transmission line, the impedance of the antenna must match the impedance of the transmission line for maximum power transfer. However, the impedance of the antenna changes with frequency, resulting in a limited range (or ranges) that the antenna can be matched to the transmission line.

[0006] In general terms, gain is a key performance figure that combines the antenna's directivity and electrical efficiency. As a transmitting antenna, the figure describes how well the antenna converts input power into radio waves headed in a specified direction. The gain of an antenna will vary across its operating bandwidth, usually peaking at the or each resonant frequency.

[0007] Antenna efficiency is a measure of what portion of the power supplied to the antenna, including any reflection loss, is actually radiated by the antenna and it is well known in the art that, in order to maximise transmission efficiency, the impedance of the source can be matched, via the antenna, to that of the medium in which the signals are to be transmitted. The medium in which signals are to be transmitted is often free space.

[0008] Horn antennas have been used for many years as a means of matching the impedance of a transmission line to that of free space and directing the radiated energy in a controlled manner by virtue of their gain characteristics. The horn antenna can be considered as an RF transformer or impedance match between the waveguide feed (supplying the input signal) and free space which has an impedance of 377 Ohms.

[0009] An accepted method of broadening the range of frequencies over which a horn antenna is impedance-matched is to introduce ridges within the horn. These are often combined with a dielectric lens or tapered periodic surface in order to aid in limiting diffraction from the horn edges, thus helping to limit the beamwidth at low frequencies. The use of ridges essentially extends the upper frequency limit over which the antenna remains well matched, since this is a function of the aperture dimensions.

[0010] A horn antenna of the types described above could be designed which permits a significant proportion of the incident energy to be radiated over a broad band. However, for the proposed application, which may involve several high-power input sources, for example, several signal generators such as microwave frequency oscillators (MFOs), the inputs may first need to be combined before being fed to the single horn antenna. This is not generally considered to be feasible at high powers, principally due to the high risk of dielectric breakdown at the combined high power, and losses in the combination process. To overcome this problem, the available antenna aperture can instead be sub-divided into a number of smaller regions, with sources attached to each region.

[0011] Alternative antenna designs comprise arrays of elements where the radiation from a number of such elements can be coherently summed in a particular direction to form a main beam. The aim in such an antenna design is to generate a single lobe from the antenna array, substantially uncorrupted by so-called grating lobes, which are spurious lobes resulting from standing waves in the elements. To minimise such grating lobe corruption, it is common for such arrays to be constructed so as to maximise the element spacing (thereby using a minimum number of elements whilst maintaining a sufficient impedance match for a specified area or aperture, to avoid the onset of grating lobes at particular scan angles. Such a spacing of elements tends to decrease efficiency due to compromised impedance matching.

[0012] Travelling wave antenna elements have been proposed for such antenna designs, for example, by Godard et al, "Size reduction and radiation optimization on UWB antenna", RADAR CONFERENCE, IEEE 2008. In this document, an antenna element is described having upper and lower conductive loop, the upper conductive loop comprising an upper conductor and a first conductive blade that tapers outwardly to form a flare portion adjacent a distal end of the upper conductor, the lower conductive loop comprising a base conductor and a second conductive blade that tapers outwardly to form a flare portion adjacent a distal end of the base conductor, the conductive loops being arranged and configured such that the outer edges of the first and second conductive blade members face each other to define a notch that tapers outwardly from the feed region of the antenna element. A conductive vane is provided between the upper conductor and the first conductive blade member to define two loops within the upper conductive loop. However, the antenna documented in this paper is designed to have one set of predefined characteristics for use in a very specific application, and the configuration of the antenna element (and the associated characteristics) are met, to a large extent, by experimentation. The field of travelling wave antennas has, thus far, received relatively very little attention compared with other types of antenna and, as such, although this and other academic papers exist that document specific travelling wave antenna designs, they provide little more general design principles for this type of antenna element that could be applied to a method of manufacturing such elements having differing characteristics and for different respective applications.

[0013] Thus, aspects of the present invention seek to provide a method of manufacturing a travelling wave antenna element that can be adapted to the manufacture of such elements having different respective performance characteristics to meet different respective needs.

[0014] Other aspects of the present invention seek to provide an efficient wide band antenna that radiates energy, possibly input from at least one high power pulsed source and fed via a co-axial line, into free space, which can be designed to optimise performance over a specified frequency band of operation.

[0015] In accordance with a first aspect of the present invention, there is provided a method of manufacturing a travelling wave antenna element, comprising the steps of:

- selecting a desired operating frequency range and selecting a predetermined required performance characteristic of said antenna element; and
- forming an antenna component having an upper and lower conductive loop by:
- providing a first conductive loop element defined by an upper conductor and a first conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said upper conductor;
- providing a second conductive loop element defined by a base conductor and a second conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said base conductor;
- placing said first and second conductive loop elements adjacent to each other such that outer edges of the first and second conductive blade members face each other to define a notch therebetween which opens outwardly from a feed region;
- providing an elongate vane between a first location on said upper conductor and a second location on said first conductive blade to define a pair of loops within said first conductive loop element; and
- matching an impedance of said antenna component, at said desired operating frequency range, to a transmission line to be connected at said feed region thereof;

wherein said step of providing said elongate conductive vane comprises:

- - selecting a minimum distance of said second location from said feed region at which said impedance match is maintained and said performance characteristic is attained, and placing said conductive vane within said first conductive loop element such that it extends from said selected second location on said first conductive blade to a first location on said upper conductor; and/or

- selecting an angle of inclination of said conductive vane within said first conductive loop at which said performance characteristic is attained, and placing said conductive vane at said selected angle of inclination between said first location on said upper conductor and said second location on said first conductive blade.

[0016] Thus, more generally, the inventors have determined, through extensive innovative input, that by changing the location and/or inclination relative to the feed region of the conductive vane within the upper loop (and, therefore, altering the size of the second loop within the upper loop), the performance of the antenna element can be optimised in respect of a predetermined desired operating frequency range. More specifically, the inventors have determined that by selecting the above-mentioned second location to be the minimum possible distance from the feed region without degrading the impedance match, the performance of the antenna element within the selected operating frequency range can be optimised. Furthermore, they have determined that characteristics or parameters of the antenna element can be influenced and optimised by selection of the inclination of the conductive vane (and, therefore, its length within an upper loop of given dimensions). The dimensions of the upper and/or lower loops can be selected according to a desired cut-off frequency of the antenna element, and the performance of the resultant antenna element, in a specified frequency range or ranges, can be optimised according to exemplary embodiments of the present invention. Such general design principles, to enable various specified performance characteristics (within the constraints of the impedance match), has never been determined, formulated or even suggested before, and is considered to provide a versatility in travelling wave antenna design that has not heretofore been available in the art.

[0017] In an exemplary embodiment of the present invention, the second location is selected as a function of the length of the upper conductor. In one exemplary embodiment, the second location on the first blade member may be at least 1/6 of the length of the upper conductor, on the basis that if the second location is too close to the feed region, the impedance match may be unacceptably degraded. In various exemplary embodiments of the invention, the distance of the second location from the feed region may be between 1/6 and 4/5 of the length of the upper conductor.

[0018] The conductive vane is, in preferred embodiments of the present invention, inclined outwardly, away from the feed region. Thus, in exemplary embodiments of the invention, the distance of the first location from the proximal end of the upper conductor may be greater than that of the second location from the feed region. Furthermore, the conductive vane may be curved along at least a portion of its length. In exemplary embodiments, the distance of the first location from the proximal end of the upper conductor may be selected as a function of the length of the upper conductor and in accordance with the selected second location. Thus, for example, when the distance of the second location from the feed region is 1/6 of the length of the upper conductor, the distance of the first location from the proximal end of the upper conductor may be 1/5 or ¼ of the length of the upper conductor. Indeed, depending on the selected second location, the first location may be between 1/5 and 5/6 along the length of the upper conductor from its proximal end.

[0019] It will be appreciated that, within a monopole member of given dimensions, the inclination of the conductive vane is determinative of its length. The method may comprise the step of selecting the length of the upper conductor and/or the base conductor according to a selected desired cut-off frequency of the antenna element.

[0020] In one specific exemplary embodiment of the invention, the length of the upper conductor and the base conductor may be around 1000mm, and the desired operating frequency range may be around 400 - 700MHz. In this case, the distance between the proximal end of the base conductor and the proximal end of the upper conductor may be around 600mm. Thus, fifteen antenna elements could be accommodated in a 3 metre wide array or space to reduce coupling. In this case, and to match an impedance of a typical MFO transmission line, the width of the first and second blade portions may be around 200mm.

[0021] The cut-off frequency of an antenna element is defined as the frequency below which an antenna cannot propagate signals. In general, the major dimension of the above-described antenna element governs the lowest frequency at which the antenna can propagate a signal. In an exemplary embodiment, the method may comprise the step of selecting the length of the upper conductor and/or the base conductor according to a selected desired cut-off frequency of the antenna element. In this case, the method may include steps of selecting a cut-off frequency of the antenna element, and selecting the peripheral dimensions of the upper loop such that, combined, they are substantially equal to a wavelength corresponding to the selected cut-off frequency. It will, therefore, be clear, that the larger the combined "circumferential" dimensions of the monopole member, the smaller will be the cut-off frequency of the antenna element.

[0022] In accordance with another aspect of the present invention, there is provided an antenna element manufactured substantially in accordance with the method described above, and comprising an upper loop and a lower loop, said upper loop comprising a first conductive loop element defined by an upper conductor and a first conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said upper conductor, said lower loop comprising a second conductive loop element defined by a base conductor and a second conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said base conductor, said first and second conductive blade members defining, between their facing edges, a notch which opens outwardly from a feed region, said upper loop further comprising an elongate conductive vane extending at an angle from a first location on said upper conductor to a second location on said first conductive blade to define a pair of loops within said upper loop, wherein an impedance of said antenna element substantially matches, at said desired operating frequency range, an impedance of a transmission line to be connected at said feed region thereof; and:

said conductive vane is located within said upper loop such that it extends from a selected second location on said first conductive blade to a first location on said upper conductor, said selected second location corresponding to a minimum distance from said feed region at which said impedance match is maintained; and/or

said conductive vane is located at a selected angle of inclination between said first location on said upper conductor and said second location on said first conductive blade to attain a selected desired characteristic.

[0023] In accordance with yet another aspect of the present invention, there is provided a wide band antenna comprising an array of antenna elements substantially as described above and/or manufactured substantially in accordance with the method described above.

[0024] These and other aspects of the present invention will be apparent from the following specific description, in which embodiments of the present invention are described, by way of examples only, and with reference to the accompanying drawings, in which:

Figure 1A is a schematic perspective view of an antenna element according to the prior art;

Figure 1B is a close-up schematic view of the feed region of the antenna element of Figure 1A;

Figure 2 is a schematic side view of an antenna element according to an exemplary embodiment of the present invention;

Figures 3A to 3E illustrate schematically various configurations of an antenna element according to an exemplary embodiment of the present invention, with progressively increasing distances of the conductive vane from the feed region of the antenna element;

Figure 4 is a graphical representation of test results for each of the five configurations illustrated in Figure 3;

Figure 5 is a graphical representation of calculations of performance from an antenna element according to an exemplary embodiment of the present invention compared with test results from two antenna elements according to the prior art;

Figures 6(i) to 6(v) illustrate various configurations of an antenna element according to an exemplary embodiment of the present invention, with progressively increasing inclinations of the conductive vane; and

Figure 7 is a graphical representation of calculations of performance for each of the five configurations illustrated in Figure 6.

[0025] In the following exemplary embodiments, an antenna is configured to be driven by microwave frequency oscillators (MFOs). However, it will appreciated that the present invention is not intended to be limited in this regard and that other multi-frequency pulsed energy sources can be used.

[0026] Throughout the specification, references are made to components being 'outward' or 'inward'. The term 'outward' has been used to indicate a direction that is towards the medium into which the antenna radiates (often referred to as boresight), and 'inward is used to indicate the opposite direction, i.e. away from the medium into which the antenna radiates. Furthermore, relative terms such as 'upper' and lower, and row and column, are used for convenience to distinguish between components so as to better explain the invention, so no absolute orientation is intended from the use of such terms alone.

[0027] Ultra Wide band (UWB) radiating systems with a peak power of around 10^{10} W are necessary for many applications. As explained above, creation of this type of radiating system has been achieved on the basis of multi element arrays with a peak radiation power of a single array element of around 0.1 - 1GW.

[0028] An antenna element has been proposed for this purpose in Koshelev, et al, "High-Power Ultrawideband Radiation Source with Multielement Array Antenna", in Proceedings of the 13th International symposium on High Current Electronics, Tomsk, Russia, July 2004. The described antenna element comprises an upper loop and a lower loop. The upper loop comprises a conductive loop defined by a first elongate conductor and a first conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of the first elongate conductor. The lower loop comprises a conductive loop element defined by a second elongate conductor and a second conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of the second elongate conductor, with the first and second conductive blade members defining, between their facing edges, a notch which opens outwardly from a feed region. It is to be appreciated that the term 'distal' used above and hereinafter is intended with reference to the feed region, i.e. outward from the feed region, and the term 'proximal' used above and hereinafter is intended with reference to the feed region, i.e. closer or closest to the feed region. An antenna comprising a 4 x 4 array of such antenna elements is described, wherein the source comprises a pulse generator feeding the antenna via four co-axial transmission lines (i.e. one feeding each row of antenna elements).

[0029] This type of antenna element was further explored by Godard, A., et al, "A transient UWB Antenna Array Used with Complex Impedance Surfaces", Hindawi, International Journal of Antennas and Propagation, Vol. 2010, wherein a modified antenna element is proposed that includes a conductive vane extending at an angle from the first conductive blade member to the upper elongate conductor so as to form a pair of adjacent loops. Such an antenna element is illustrated schematically in Figure 1A of the drawings, in which it can be seen that the element comprises an upper loop 1 comprising a first conductive loop element 2 and a lower loop 3 comprising a second conductive loop element 4. The conductive loop element 2 of the upper loop 1 comprises an elongate upper conductor 9 and a first conductive blade member 10, the first conductive blade member tapering outwardly from a feed region 7 to the distal end of the upper conductor 9 to form a first flare 11. The conductive loop element 4 of the lower loop 3 comprises an elongate base conductor 5, oriented substantially parallel to the upper conductor 9, and a second conductive blade member 6 which tapers outwardly from the feed region 7 to the distal end of the base conductor 5 to form a second flare 8.

[0030] A conductive vane 12 extends at an angle across the conductive loop of the monopole member, between the second blade member and the upper conductor, the vane 12 being inclined outwardly, i.e. away from the feed region 7. The feed region 7 is defined at a back plate 13. The connection or transition between the first blade member 6 and the inner surface of the back plate 13 is designed to achieve a good impedance match (S11 parameter lower the -10dB) over a desired frequency band (300MHz - 3GHz). As shown in Figure 1B of the drawings, the transition is formed of two sections: a first section 14 formed of metal and a second, central section 15 formed of, for example, PTFE, that provides high-voltage resistance.

[0031] However, it will be appreciated, that the described antenna element is intended for a specific use and frequency range, and has been developed and optimised for that use and frequency range. In contrast, an object of aspects of the present invention is to provide a method of antenna design that permits the design of an antenna element with a specified cut-off frequency, and permits the performance of such an antenna element or a wide band antenna comprising an array of such elements to be optimised according to specified characteristics, without increasing the dimensions of the antenna element to levels that would make it impractical for many applications.

[0032] The object of the above-mentioned reference (Godard) is to present a miniature antenna element which can be shown to have a cut-off frequency of 363MHz. This characteristic is determined by the external characteristics of the antenna element, i.e. height H, length L and width W. In order to reduce the cut-off frequency of the element, it would be necessary to increase the external dimensions significantly, with the result that the antenna element, and any resulting multi-element array antenna would have impractically large dimensions for many applications, and may have an inadequate performance at various frequency ranges. Using the design calculations employed by Godard *et al*, a cut-off frequency of around 100MHz, would require an antenna element of dimensions:

$$W = 3000/10 = 300mm$$

$$H = 3000/5 \quad = 600mm$$

$$L = 3000/3.85 = 780mm$$

[0033] Thus, the width of each antenna element would have to be 300mm. However, this also has additional drawbacks in terms of heat dissipation and, therefore, a negative effect on efficiency of the antenna element. Also, such dimensions may make it difficult to impedance-match the antenna element, or a multi-element antenna, to the transmission lines(s), which is a significant drawback as the feed design is, in many cases, critical to driving the antenna. Furthermore, such dimensions would not provide an optimised performance at specified frequencies and frequency ranges, and no methods or techniques are proposed in the prior art for solving these issues.

[0034] It is, therefore, an object of aspects of the invention to provide a method of antenna design, wherein its performance can be optimised at a specified operational frequency range and with reduced dimensions compared with known techniques.

[0035] In accordance with invention, this object may be achieved by altering the location and/or the inclination of the conductive vane defining the double loop in the upper loop of an antenna element of the type described above.

[0036] Referring to Figure 2, in an exemplary embodiment of the invention, the antenna element structure proposed is of the type described above, but having the following dimensions:

$$W = 200mm;$$

$$H = 600mm;$$

$$L = 1000mm;$$

which dimensions are selected to provide a cut-off frequency of ~100MHz.

[0037] In a method of manufacture according to an exemplary embodiment of the invention, impedance matching is performed to match the impedance of the antenna element to the transmission line of the desired radiation source (in a known manner) and the feed region 7 is thus optimised. Next, a selected operating frequency range for which the antenna element performance is to be optimised is selected. In this example, the frequency range is 400 - 700MHz.

[0038] The inventors have determined that by selecting the location of the conductive vane 12, the performance of the antenna element in the operating frequency range 400 - 700MHz can be optimised (in terms of return loss and efficiency.

[0039] Referring to Figure 3 of the drawings, 5 possible locations of the conductive vane are illustrated, as A, B, C, D and E respectively. The inventors have determined, through extensive innovative input, that the key aspect of this element of the design method is the distance from the feed region 7 of the end of the conductive vane 12 where it meets the blade member of 10. In each of the five illustrated tests A-E, the inclination of the vane 12, outward, is substantially the same, at less than 10° relative to a vertical axis defined by the back plate 13, and the above-mentioned distance from the feed region 7 of the vane 12 where it meets the blade member 10 is made progressively larger.

[0040] As illustrated in Figure 4 of the drawings, it can be seen that if this distance is too small, the impedance match is degraded and the return loss (S11) is increased above an acceptable level at some frequencies. However, it can be seen that the performance of the antenna in the frequency range 400 - 700MHz is significantly improved in tests B, C and D at least (i.e. with the above-mentioned distance between about L/6 and 5L/8.

[0041] This performance can be seen in Figure 5 (reference 3) in comparison to that achieved with a comparably sized antenna element having (1) a single loop (Koshelev) and (2) a much larger double loop (Godard), wherein the above-mentioned distance is L/4 and the inclination of the vane is such that the distance of the other end of the vane from the proximal end of the upper conductor is L/2.

[0042] Referring now to Figure 6 of the drawings, having determined the optimum distance from the feed region of the conductive vane where it meets the blade member, the inventors have determined that the performance of the antenna element can be further optimised by changing the length of the inner loop (closest to the feed region). In effect, this method step comprises selecting an inclination of the conductive vane (outward) relative to the vertical axis defined by the back plate, or (equally) selecting the distance from the proximal end of the upper conductor of the conductive vane where it meets the upper conductor.

[0043] In the examples shown in Figure 6, each of the configurations tested has a 'bottom' distance (from the feed region) of around L/6 (corresponding to Test B of Figure 3), and each of the test configurations has a progressively larger loop length, ranging from about L/5 in test (i) to around 4L/5 in test (v). Thus, as shown in the calculated results illustrated in Figure 7 of the drawings, the performance of the antenna element can be optimised for a specified operating frequency range (in this case, 400 - 700MHz) by maintaining the minimum 'bottom' distance of the conductive vane (whilst maintaining the required impedance match), but increasing the size of the inner loop by increasing the 'top' distance (from the proximal end of the upper conductor) or inclination of the conductive vane. In view of the increased length of the upper and/or lower loops in comparison to the above-referenced Godard design, the antenna performance is further optimised by the methods proposed herein.

[0044] Thus, more generally, the cut-off frequency of the antenna can be selected and the loop length/dimensions selected to achieve that selected cut-off frequency. The performance of the resultant antenna can then be optimised for a specified frequency range or ranges using methods according to exemplary embodiments of the present invention.

[0045] It will be apparent to a person skilled in the art, from the foregoing description, that modifications and variations can be made to the described embodiments without departing from the scope of the invention as defined by the appended claims.

Claims

1. A method of manufacturing a travelling wave antenna element, comprising the steps of:

- selecting a desired operating frequency range and selecting a predetermined required performance characteristic of said antenna element; and
- forming an antenna component having an upper and lower conductive loop by:
    - ◦ providing a first conductive loop element defined by an upper conductor and a first conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said upper conductor;
    - ◦ providing a second conductive loop element defined by a base conductor and a second conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said base conductor;
    - ◦ placing said first and second conductive loop elements adjacent to each other such that outer edges of the first and second conductive blade members face each other to define a notch therebetween which opens outwardly from a feed region;
    - ◦ providing an elongate vane between a first location on said upper conductor and a second location on said first conductive blade to define a pair of loops within said first conductive loop element; and
    - ◦ matching an impedance of said antenna component, at said desired operating frequency range, to a transmission line to be connected at said feed region thereof;

wherein said step of providing said elongate conductive vane comprises:

- selecting a minimum distance of said second location from said feed region at which said impedance match is maintained and said performance characteristic is attained, and placing said conductive vane within said first conductive loop element such that it extends from said selected second location on said first conductive blade

to a first location on said upper conductor; and/or
- selecting an angle of inclination of said conductive vane within said first conductive loop at which said performance characteristic is attained, and placing said conductive vane at said selected angle of inclination between said first location on said upper conductor and said second location on said first conductive blade.

2. A method according to claim 1, including the step of selecting the second location as a function of the length of the upper conductor.

3. A method according to claim 2, wherein the second location on the first blade member is at least 1/6 of the length of the upper conductor.

4. A method according to claim 3, wherein the distance of the second location from the feed region is between 1/6 and 4/5 of the length of the upper conductor.

5. A method according to any of the preceding claims, wherein the conductive vane is inclined outwardly, away from the feed region, such that the distance of the first location from the proximal end of the upper conductor is greater than that of the second location from the feed region.

6. A method according to any of the preceding claims, wherein the conductive vane is curved along at least a portion of its length.

7. A method according to any of the preceding claims, comprising the step of selecting the distance of the first location from the proximal end of the upper conductor as a function of the length of the upper conductor and in accordance with the selected second location.

8. A method according to claim 7, wherein, when the distance of the second location from the feed region is 1/6 of the length of the upper conductor, the distance of the first location from the proximal end of the upper conductor is 1/5 or ¼ of the length of the upper conductor.

9. A method according to claim 7, wherein the first location is between 1/5 and 5/6 along the length of the upper conductor from its proximal end.

10. A method according to any of the preceding claims, comprising the step of selecting the length of the upper conductor and/or the base conductor according to a selected desired cut-off frequency of the antenna element.

11. A method according to claim 10, including the steps of selecting a cut-off frequency of the antenna element, and selecting the peripheral dimensions of the upper loop such that, combined, they are substantially equal to a wavelength corresponding to the selected cut-off frequency.

12. An antenna element manufactured substantially in accordance with the method of any of the preceding claims, and comprising an up per loop and a lower loop, said upper loop comprising a first conductive loop element defined by an upper conductor and a first conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said upper conductor, said lower loop comprising a second conductive loop element defined by a base conductor and a second conductive blade member that tapers outwardly to form a flare portion adjacent a distal end of said base conductor, said first and second conductive blade members defining, between their facing edges, a notch which opens outwardly from a feed region, said upper loop further comprising an elongate conductive vane extending at an angle from a first location on said upper conductor to a second location on said first conductive blade to define a pair of loops within said upper loop, wherein an impedance of said antenna element substantially matches, at said desired operating frequency range, an impedance of a transmission line to be connected at said feed region thereof; and:

said conductive vane is located within said upper loop such that it extends from a selected second location on said first conductive blade to a first location on said upper conductor, said selected second location corresponding to a minimum distance from said feed region at which said impedance match is maintained; and/or
said conductive vane is located at a selected angle of inclination between said first location on said upper conductor and said second location on said first conductive blade to attain a selected desired characteristic of said antenna element.

13. A wide band antenna comprising an array of antenna elements according to claim 14.

Fig. 1A

Prior Art

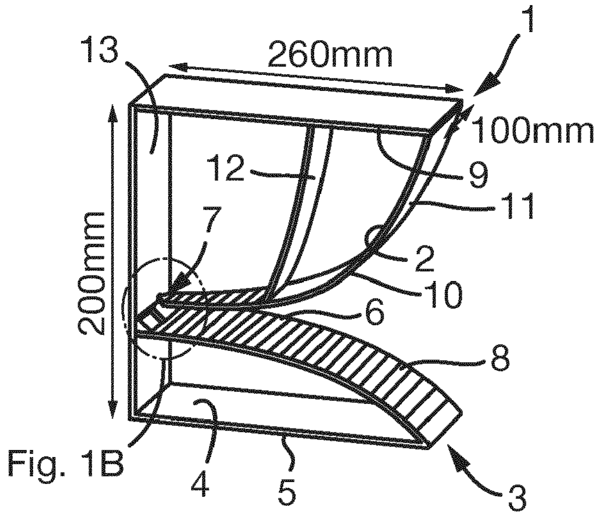


Fig. 1B

Prior Art

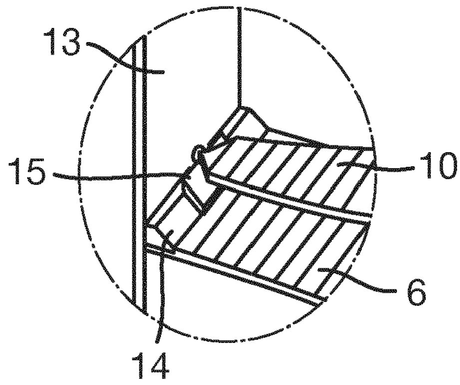


Fig. 2

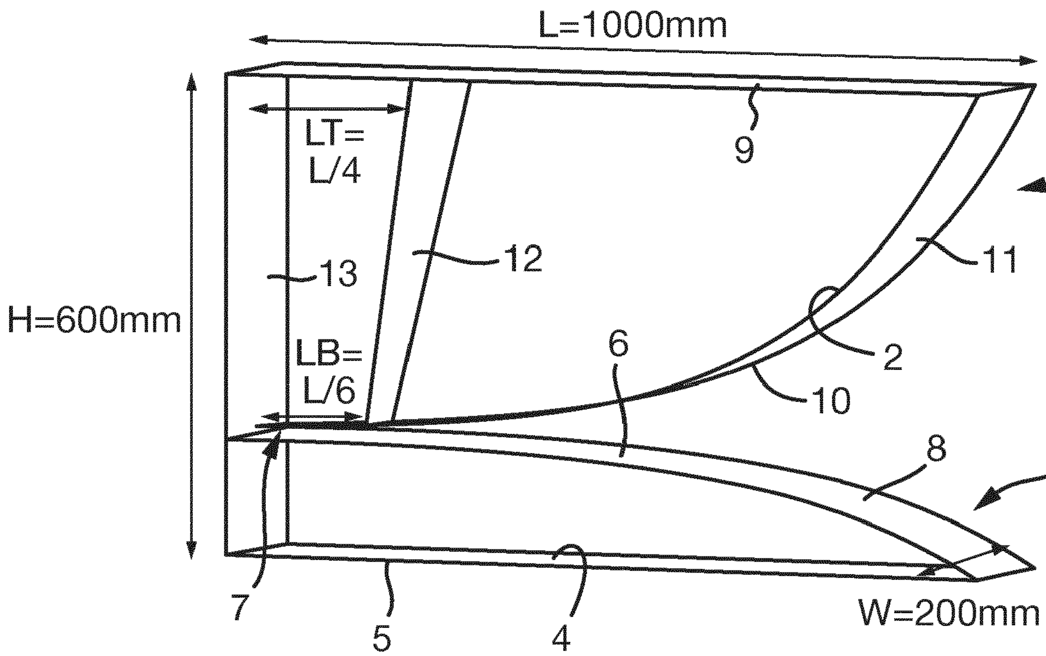


Fig. 4

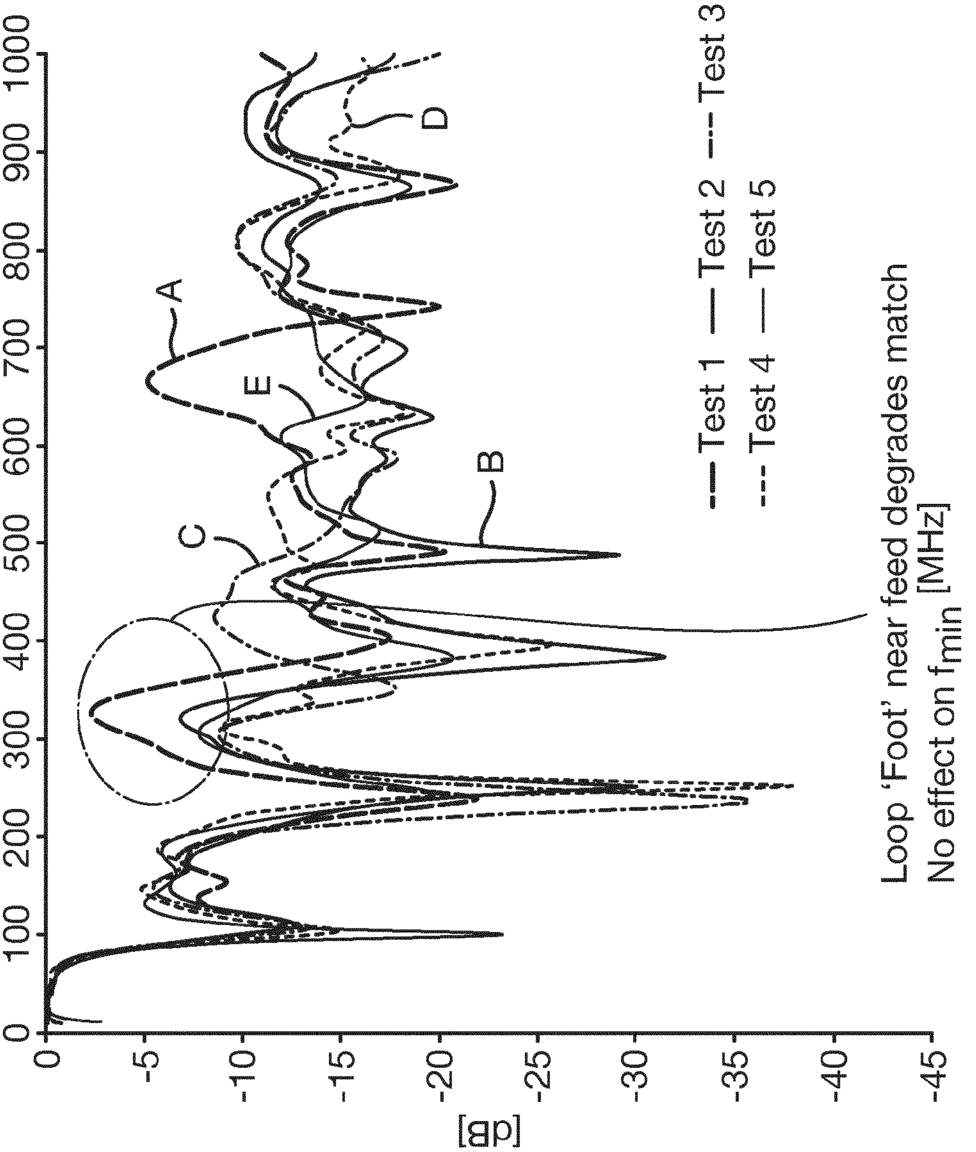

[dB]
[MHz]
A
B
C
D
E
Test 1
Test 2
Test 3
Test 4
Test 5
Loop 'Foot' near feed degrades match
No effect on f_{min}

Fig. 3

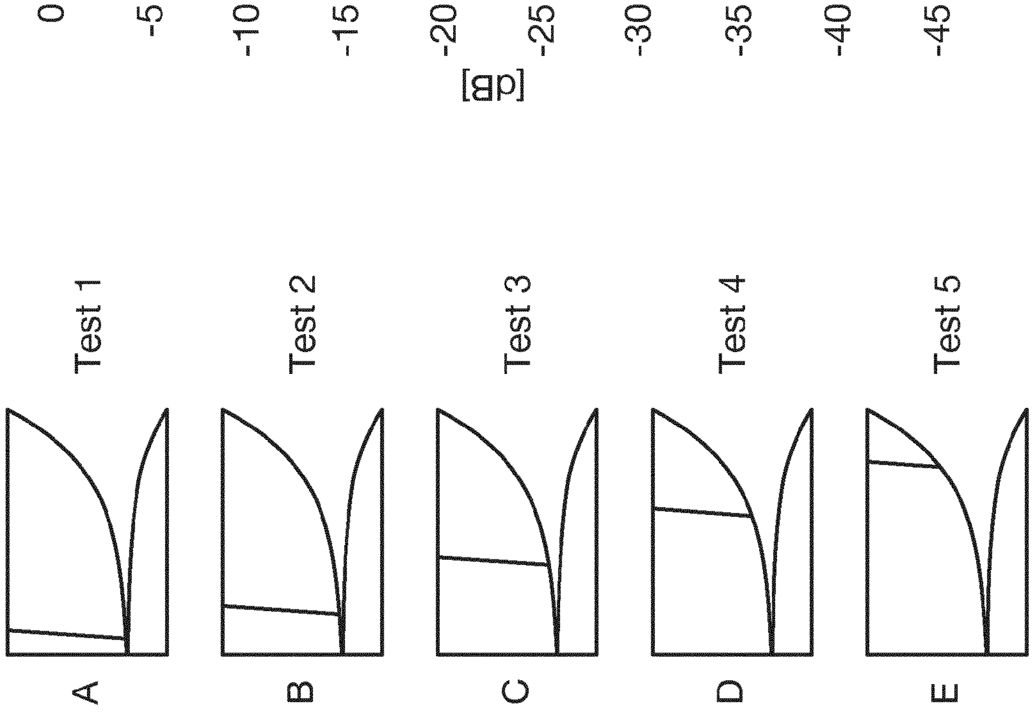

Test 1
Test 2
Test 3
Test 4
Test 5
A
B
C
D
E

Fig. 5

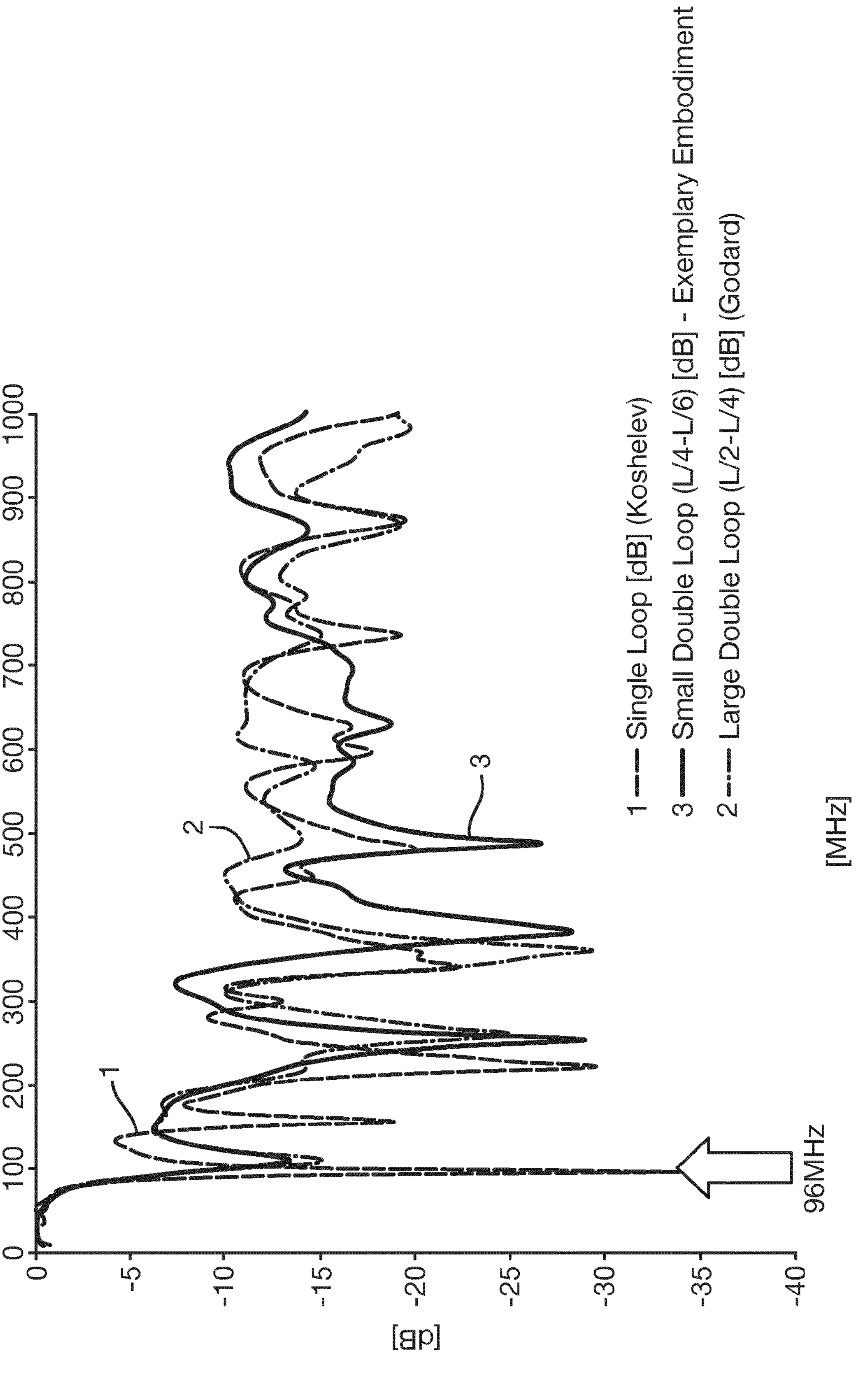

[dB]
0
-5
-10
-15
-20
-25
-30
-35
-40
0
100
200
300
400
500
600
700
800
900
1000
[MHz]
96MHz
1
2
3
1 Single Loop [dB] (Koshelev)
3 Small Double Loop (L/4-L/6) [dB] - Exemplary Embodiment
2 Large Double Loop (L/2-L/4) [dB] (Godard)

Fig. 6

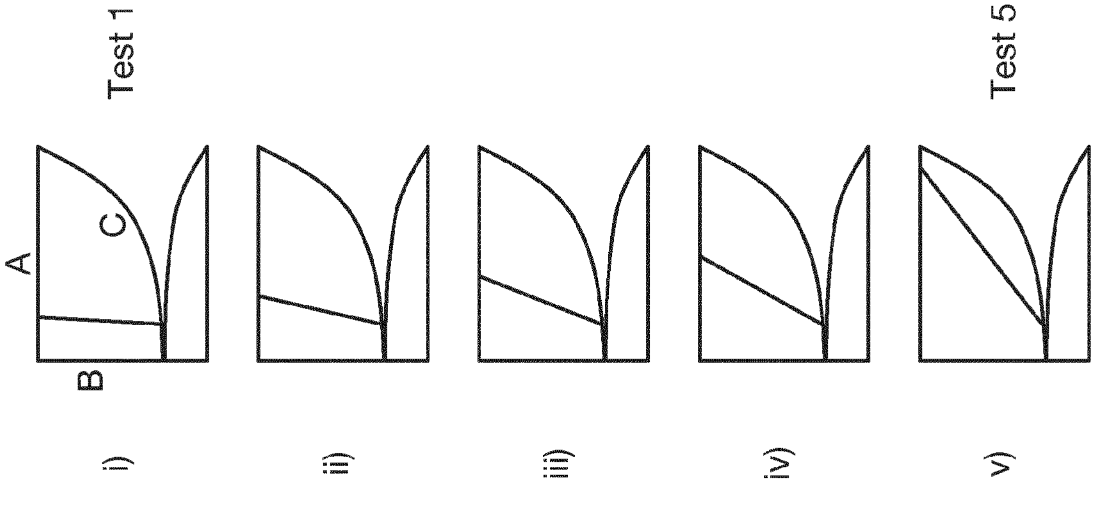
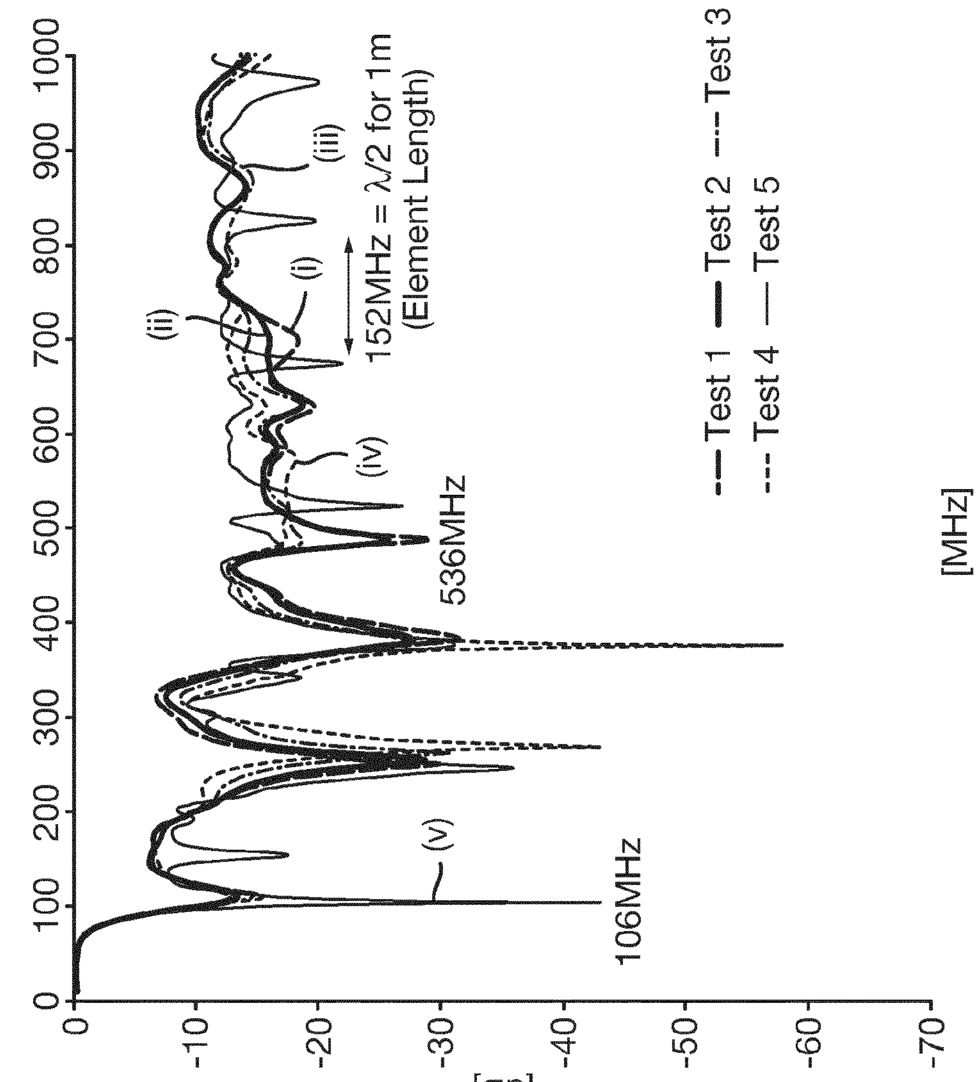

Test 1
A
C
B
Test 5
i)
ii)
iii)
iv)
v)

Fig. 7


[dB]
[MHz]
0
-10
-20
-30
-40
-50
-60
-70
0
100
200
300
400
500
600
700
800
900
1000
106MHz
536MHz
152MHz = λ/2 for 1m
(Element Length)
(i)
(ii)
(iii)
(iv)
(v)
Test 1
Test 2
Test 3
Test 4
Test 5

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EUROPEAN SEARCH REPORT

Application Number
EP 16 20 3814

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,D	GODARD A ET AL: "Size reduction and radiation optimization on UWB antenna", RADAR CONFERENCE, 2008. RADAR '08. IEEE, IEEE, PISCATAWAY, NJ, USA, 26 May 2008 (2008-05-26), pages 1-5, XP031376259, ISBN: 978-1-4244-1538-0 * pages 1,2 * -----	1-13	INV. H01Q13/08 H01Q21/06 H01Q7/00
X	DESRUMAUX L ET AL: "Transient measurements of an agile UWB array", WIRELESS TECHNOLOGY CONFERENCE (EUWIT), 2010 EUROPEAN, IEEE, PISCATAWAY, NJ, USA, 27 September 2010 (2010-09-27), pages 153-156, XP031784819, ISBN: 978-1-4244-7233-8 * page 153 - page 154 * -----	1-13	
X,D	A. GODARD ET AL: "A Transient UWB Antenna Array Used with Complex Impedance Surfaces", INTERNATIONAL JOURNAL OF ANTENNAS AND PROPAGATION, vol. 12, no. 24, 2010, pages 329-8, XP055278410, ISSN: 1687-5869, DOI: 10.1109/8.59765 * 2. The Elementary Antenna * -----	1-13	TECHNICAL FIELDS SEARCHED (IPC) H01Q

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	5 May 2017	Jäschke, Holger

CATEGORY OF CITED DOCUMENTS

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Non-patent literature cited in the description

- Size reduction and radiation optimization on UWB antenna. **GODARD et al.** RADAR CONFERENCE. IEEE, 2008 **[0012]**
- **KOSHELEV et al.** High-Power Ultrawideband Radiation Source with Multielement Array Antenna. *Proceedings of the 13th International symposium on High Current Electronics, Tomsk, Russia,* July 2004 **[0028]**
- **GODARD, A. et al.** A transient UWB Antenna Array Used with Complex Impedance Surfaces. *Hindawi, International Journal of Antennas and Propagation,* vol. 2010 **[0029]**