

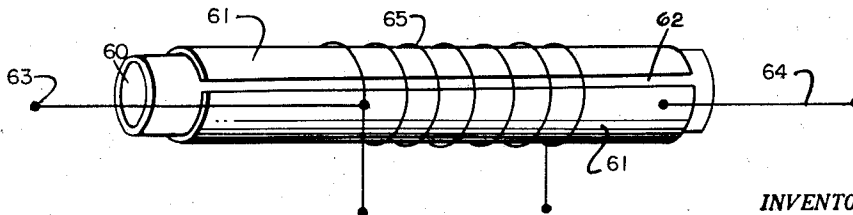
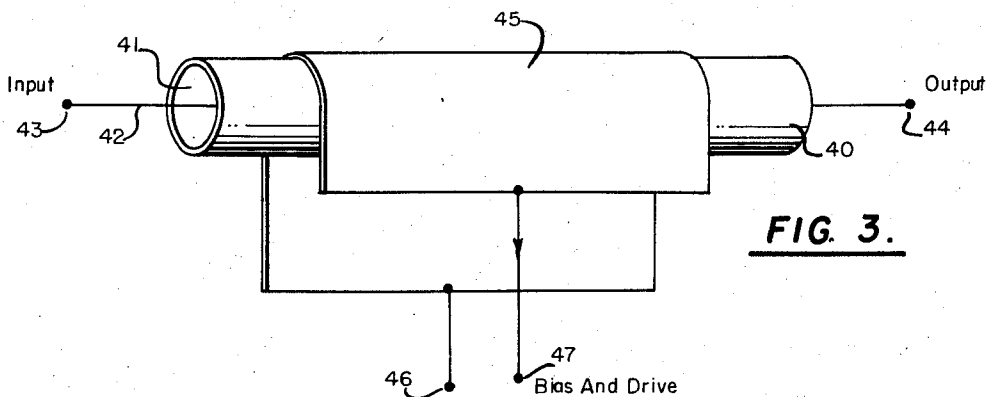
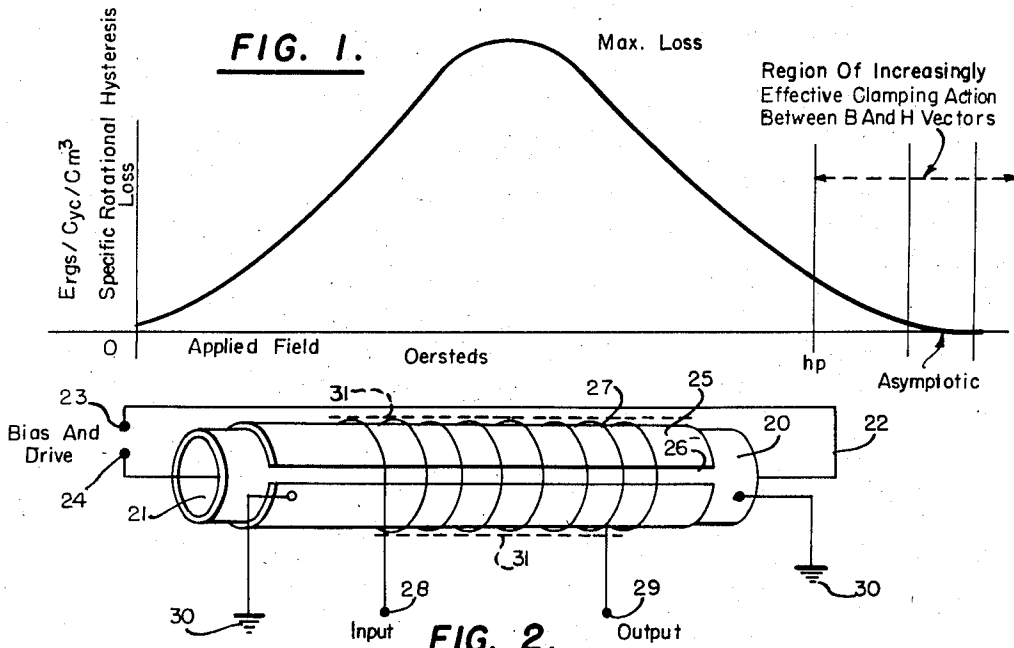
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TRANSVERSE MAGNETIC TRAVELING WAVE AMPLIFIERS

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TRANSVERSE MAGNETIC TRAVELING WAVE AMPLIFIERS

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8 Claims. (Cl. 179—171)

The present invention concerns a transverse magnetic traveling wave amplifier.

It is an object of the invention to provide a transverse magnetic amplifier structure which will yield a substantially square wave output pulse rather than one exhibiting exponential decay.

It is an object of the invention to provide a transverse magnetic amplifier which will admit the information to be amplified as a pulse train in the case of ultra high frequency signals or as a signal pulse in the case of radio frequency applicable to present-day digital computers, to a delay line incorporating a ferrite ferromagnetic dielectric comprising, in one form a coaxial continuous parameter delay line designed around a tube of ferrite.

It is an object of the invention to provide a ferromagnetic transverse amplifier comprising a delay line in which the input information propagates down the delay line, and when all of the information to be amplified in one operation, comprising the propagation, is momentarily stored in a delay line, the ferrite dielectric forming a part of the device is suddenly exposed to an increase in the transverse magnetic bias applied to it. It will be understood that the delay line dielectric, for example the ferrite mentioned above, is always transversely biased magnetically in an orientation everywhere at right angles to the direction of any magnetic field which can be produced by signal information which propagates down the delay line. This steady D.C. transverse bias is, at selected times, augmented by a drive current which increases the transverse bias to a higher value after the manner discussed in the lumped parameter forms in my copending application Serial No. 494,907, now Patent No. 2,811,652, for: "Pulse Type Transverse Magnetic Amplifier."

The larger value of the transverse bias is maintained until all the information has left the delay line, after which time the transverse bias can be restored to its lower steady state value to await the next amplifying operation. The net result of this form of the invention is that the signal information traveling down the delay line emerges at the end of the line in amplified state, that is, as the transverse bias is in the process of being increased to its high value by the drive pulse, all the current elements in the various portions of the delay line are simultaneously magnified or amplified in exactly the same way, and this magnification also occurs in the case of the lumped parameter transverse amplifiers discussed in my copending application, mentioned above.

Magnetic materials having rectangular hysteresis characteristics may be here employed. For a detailed discussion of transverse magnetic amplifiers in connection with the present invention, reference is made to the following copending application:

Serial No. 494,903, for "Transverse Magnetic Amplifier," filed on even date herewith.

Like numerals in the drawings refer to like parts throughout.

Figure 1 is a composite loss diagram for selected magnetic materials having various hysteretic constants.

Figure 2 is a schematic diagram of one form of transverse traveling wave magnetic amplifier.

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Figure 3 is a modification of the showing in Figure 2; and

Figure 4 is a schematic representation of a ferrite micro-second delay line according to the invention.

The basic considerations concerning transverse devices comprising the present invention may be formulated as follows:

(1) Transverse fields are in general applied to a core of ferromagnetic material simultaneously. It may be noted that the B—H relationships are quantitatively unknown except under the conditions to be described below.

(2) It is possible by means of the invention to obtain quantitatively predictable B—H relationships in transverse core structures, consisting in the resultant B vector being a simple mathematical function of the resultant H vector.

(3) The above is accomplished by observing strictly the condition that the scalar magnitude of the vector resultant magnetizing force be kept above a predeterminable level characteristic of the magnetic material.

A. When the above condition is met, the vector flux density B is substantially given by the vector equation:

$$(1) \quad \vec{B} = \frac{B_s \vec{H}}{h}$$

where B_s is the saturation flux density magnitude for the material; $\vec{H}$ is the resultant magnetizing force vector in the material; and h is the scalar magnitude of $\vec{H}$.

The above equation states that $\vec{B}$ is in the same direction as $\vec{H}$ and has the fixed magnitude B_s . This relationship is justified and occurs when the above condition is satisfied.

B. When Equation 1 is satisfied, the core itself does not absorb or store energy even temporarily, but merely serves to transfer energy between the sources of the transverse fields, yielding loss-less operation.

(4) Condition 3 above is met by having at least two transverse fields satisfying the condition:

$$(2) \quad h \geq hp$$

where hp is the predeterminable level referred to in 3 above.

(5) In a practical embodiment, a transverse magnetic structure, constructed in accordance with the foregoing considerations, would comprise a body of magnetic material having magnetizing means associated therewith and adapted to impress mutually orthogonal fields on the said body. An output effect may be produced from such a transverse structure by varying the magnitude of at least one of the transverse fields and, so long as the condition represented by Equation 2 is satisfied, the operation of the device will be substantially loss-less.

(6) The predeterminable level hp referred to above may be taken to be that value of magnetizing field larger than the value at which the specific rotational hysteresis loss for the material peaks (see Figure 1) and for which the specific rotational hysteresis loss is appreciably less than said maximum rotational hysteresis loss.

It will be seen from the above that the mutual inductance is not the result of a single field, but is produced by the oscillation of B_s through the angle θ due to the interaction of the two fields and the change in the resultant H_r with its effect on B_s .

The analysis of the traveling wave transverse amplifier is complicated by the changes in the transverse bias which also produce changes in the characteristic impedance and delay time of the ferrite delay line. In the case of traveling wave transverse amplifiers, the problem of preventing the feedback of energy from the output to the input or input source is simply the problem of how

to attenuate any backward traveling waves which may be induced in the delay line in the amplifying process. To amplify a pulse to best advantage separation between input and output is effected by virtue of continuity, direction and delay of the pulse in the line. Bias is always present and drive is applied after an input pulse train has propagated so that it is all in the line. The drive pulse is applied and maintained until the entire pulse train has been received as a signal and is out of the line. The action amplifies the signal and time duration is decreased as seen at the output. For example, during the time period that the transverse bias is being increased, if no such backward traveling waves are generated during this process, the problem reduces itself merely to that of how to terminate the delay line correctly. One way in which backward traveling waves, originating in the amplifying process, can be attenuated is to decrease the transverse bias to its steady state value while the backward traveling wave components are still in the delay line. It is, however, equally important that this action take place after the forward traveling waves carrying the useful output information have left the delay line, as it is desirable that they are not also attenuated by the decrease in bias.

This action can be accomplished by making the delay line several times longer than is necessary to hold the input pulse train or pulses, and to postpone the rise of the transverse bias until the pulse train nears the end of the delay line. The forward traveling waves will be amplified and immediately emerge from the delay line while any background traveling waves will have to travel back through the larger part of the delay line and so will still be in the line when the transverse bias is reduced. They will then be attenuated by a process which is the reverse of that which occurs when the transverse bias is increased.

In Figure 2 is shown one form of traveling wave transverse magnetic amplifier, for use with single computer pulses or radio frequency information. An elongate cylindrical core 20, of ferromagnetic material is provided with a central channel 21 threaded by a combined bias and drive winding 22. Although winding 22 is shown as a single turn, it must be understood that as many turns may be employed as good design indicates. This consideration will apply throughout the other figures in this case.

Combined bias and drive winding 22 is supplied with terminals 23, 24 for the application of appropriate voltages. Around the outer surface of ferrite tube 20 is a metallic coating 25, which serves as a capacitive ground plane of the delay line. A break 26 is made in the metallic coating to prevent or rather limit eddy currents when the longitudinal flux changes in the ferrite tube. On top of the metallic coating 25 is wound an input-output coil 27 having an input terminal 28 and an output terminal 29. The coating 25 is grounded at 30. After the input-output coil 27 has been wound, an additional conducting coating, with a gap directly above and corresponding to gap 26, may be applied to the outside of the winding to increase the capacitance per unit length of the delay line. Such an outer coating should, of course, be grounded to the inner coating and is indicated provisionally by the dotted line 31.

The configuration of the device shown in Figure 2 insures a relatively long delay time for waves traveling along the helical winding 27. Waves traveling through the bias drive winding 29, however, will travel much more rapidly than the signal waves travel on the helix and so will overtake those on the helix as rapidly as desired, depending upon the length of the helical winding and because the increase in the transverse bias should appear to be almost simultaneous along the entire delay line comprising the device. A drive pulse at terminals 23, 24 occurs after an input pulse train has propagated so that it is all in the line. The drive pulse augments the exist-

ing D.C. bias until the entire pulse train has been received as a signal and is out of the line.

In Figure 3, a traveling wave transverse magnetic amplifier is illustrated for use with ultra high frequency or microwave pulse trains. This type of device is applicable to radar systems and the like. An elongate tube of ferromagnetic material 40 is provided with a central channel 41 threaded by an input-output winding 42 having an input terminal 43 and an output terminal 44. The material of tube 40 acts as a dielectric of the delay line. Tube 40 is surrounded by a conducting sheet 45 having an input 46 and an output 47 comprising the bias and drive circuits. Conducting sheet 45 forms a single turn around the ferrite tube 40 and carries the total transverse bias current, and may also act as the "ground plane" or outer conductor of the coaxial cable from which the structure is derived. However, it will be evident that this latter function could be served equally well by a conductive coating applied to the outside of the ferrite tube and having a lengthwise gap such as that shown in Figure 2, above.

In the structure of Figure 3, the signal traveling down the central wire of the coaxial line 42 is not affected by either of the following two effects which are present in the structure of Fig. 2. (1) Self-demagnetizing tendencies in the ferrite material 40, and (2) long-range inductive coupling between distant elements in the delay line through the agency of the ferrite tube 40. It is true that self-demagnetizing effects are still present, but these affect only the bias and drive circuits of the plate 45. The use of a single wide conducting strip, such as 45, for the bias drive coil, is desirable in order that the changes in transverse bias be applied to all elements of the delay line as nearly simultaneously as is possible. The bias drive sheet 45 should be made very thin in order to minimize eddy currents which would tend to counteract the function just mentioned. The relation of the rise time of the drive pulses applied to terminal 46 to that of the pulses being amplified should be as small as possible, but not so small as to interfere with the operation of the amplifier.

A delay line may be made of a tube coated with conductive silver paint having a clear gap, as discussed in connection with Figure 2. Two ground leads of copper wire can be connected to or embedded in the silver paint. The main delay helix is wound on the coated tube and may take the form of No. 38 high frequency copper wire, close-wound in 600 turns, occupying a substantial portion of the length of the tube. An additional layer of silver paint may then be coated on the outside of the helix, again, having an eddy current preventive gap which lies above and corresponds to the gap of the first coating, as illustrated and described in connection with Figure 2. The second coating is connected to the first by painting over the ends of the helix, thus, effectively grounding both coatings by a suitable means such as 30, shown in Figure 2.

Such a device is illustrated in Figure 4, in which a ferrite core 60 is supplied with a coating of conducting silver paint 61 to serve as a ground plane for its delay line. A clear path 62 is scratched or filed in the silver coating to break the eddy current circuit. A ground wire 63 of about 1 mil is embedded as a lead in silver coating 61. A second ground wire 64 is embedded in the opposite end of the silver coating 61. A 600-turn helix 65 is closely wound around the silver coating 61. It will be understood that the above values are representative and are supplied for the purposes of illustration only. They are not to be taken as in any sense limiting.

While there have been described above what are at present believed to be preferred forms of the invention, the disclosure will suggest variations and equivalent structures to those skilled in the art. All such variants and equivalent structures which fall within the true spirit of the invention are intended to be covered by the generic terminology of the appended claims.

I claim:

1. A traveling wave transverse magnetic amplifier comprising a saturable magnetic element, a plurality of winding means linked to at least a part of said element for producing magnetic fields respectively in first and second transverse directions of magnetization in the same part of said element, means for energizing at least a part of each of said winding means simultaneously and at least a part of each of said winding means in a varying amount to produce varying fields in both said directions and with the energizations being such that the net magnetizing force produced by said winding means when energized is sufficient to drive said same part of said element to substantial saturation, a conductive element mounted adjacent said magnetic element in capacitive relation to at least one of said winding means, and means for deriving from a part of one of said winding means output signals that vary in accordance with the variations in energization of the other of said winding means, said output signal deriving means including a common return circuit connected to said conductive element.

2. A delay line comprising an element of magnetic material, means for applying a first magnetic field to said element including a first winding means, and a first means for energizing said first winding means, means for applying a second magnetic field to said element simultaneously with said first field including a second winding means, and a second means for energizing said second winding means, said first and second winding means being linked to said element in transverse directions so that said fields are non-parallel and intersect each other at an angle in said material, the energizations supplied by said first and second energizing means being such that the field in each of said directions has a variable magnitude and said fields have a moving resultant that saturates said element and the resultant saturated magnetic flux moves and tends to follow the movement of the resultant of said fields whereby operation of the amplifier is in the region of decreasing rotational hysteresis loss, a conductive element mounted adjacent said element in capacitive relation to one of said winding means and connected in circuit therewith, and means for deriving output signals connected to one of said winding means.

3. A transverse magnetic amplifier delay line comprising, in combination, a magnetic core, a bias and drive winding means linking said core along a first axis, means for energizing said bias and drive winding means to produce a saturating bias field which carries the core material into the region of effective clamping action between the resultant saturating magnetizing field and the saturated magnetic flux and into the region of vanishing hysteresis loss for energizing said bias and drive winding with alternating current for superimposing an alternating field on said bias field to produce a variation in the amplitude of the resulting magnetizing field within said region of effective clamping action, winding means linking said core along a second, transverse axis, a circuit connected to said second axis winding means and having signal input terminals, and means connected to said second axis winding means including an output terminal for deriving an output signal, artificial delay line means including, a conductive element mounted adjacent said magnetic element in capacitive relation to said second axis winding means

and connected in a common circuit path with one of said input terminals and with said output means, and means connected to said input terminals for applying thereto input signals causing changes in direction of the resultant saturating magnetizing field and the saturated magnetic flux clamped together, whereby amplified output signals are produced in accordance with said input signals.

4. The combination of claim 3, wherein said core is tubular and made of a ferrite dielectric material and arranged as a dielectric for the capacitance of said conductive element and second axis winding means, one of said winding means extends axially and the other around said core, and said conductive element includes a layer of conductive material mounted around a surface of said core.

5. The combination of claim 4, wherein said conductive layer has its ends spaced apart axially along said core to reduce eddy currents therein.

6. The combination of claim 5, wherein said conductive layer is a coating of metal attached around the outside of said tubular core.

7. The combination of claim 6, wherein said conductive coating is a coating of silver paint with an unpainted path extending axially the length thereof, and said common circuit path includes a ground wire embedded in said coating.

8. A transverse magnetic amplifier delay line comprising a saturable magnetic element in the form of a tube, a plurality of winding means linked to at least a part of said element for producing fields respectively in first and second transverse directions of magnetizations in the same part of said element, means for energizing at least a part of each of said winding means simultaneously and at least a part of each of said winding means in a varying amount to produce varying fields in said directions and with the energizations being such that the net magnetizing force produced by said winding means when energized is sufficient to drive said same part of said element to substantial saturation and to produce a resultant magnetization that varies in direction with variations in said first direction field, means for deriving from a part of one of said winding means output signals that vary in accordance with variations in direction of said resultant magnetization, and artificial delay line means including a conductive element mounted adjacent said magnetic element in capacitive relation to at least one of said winding means, said conductive element including one of said winding means in the form of a conductive sheet around said tubular magnetic element.

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