

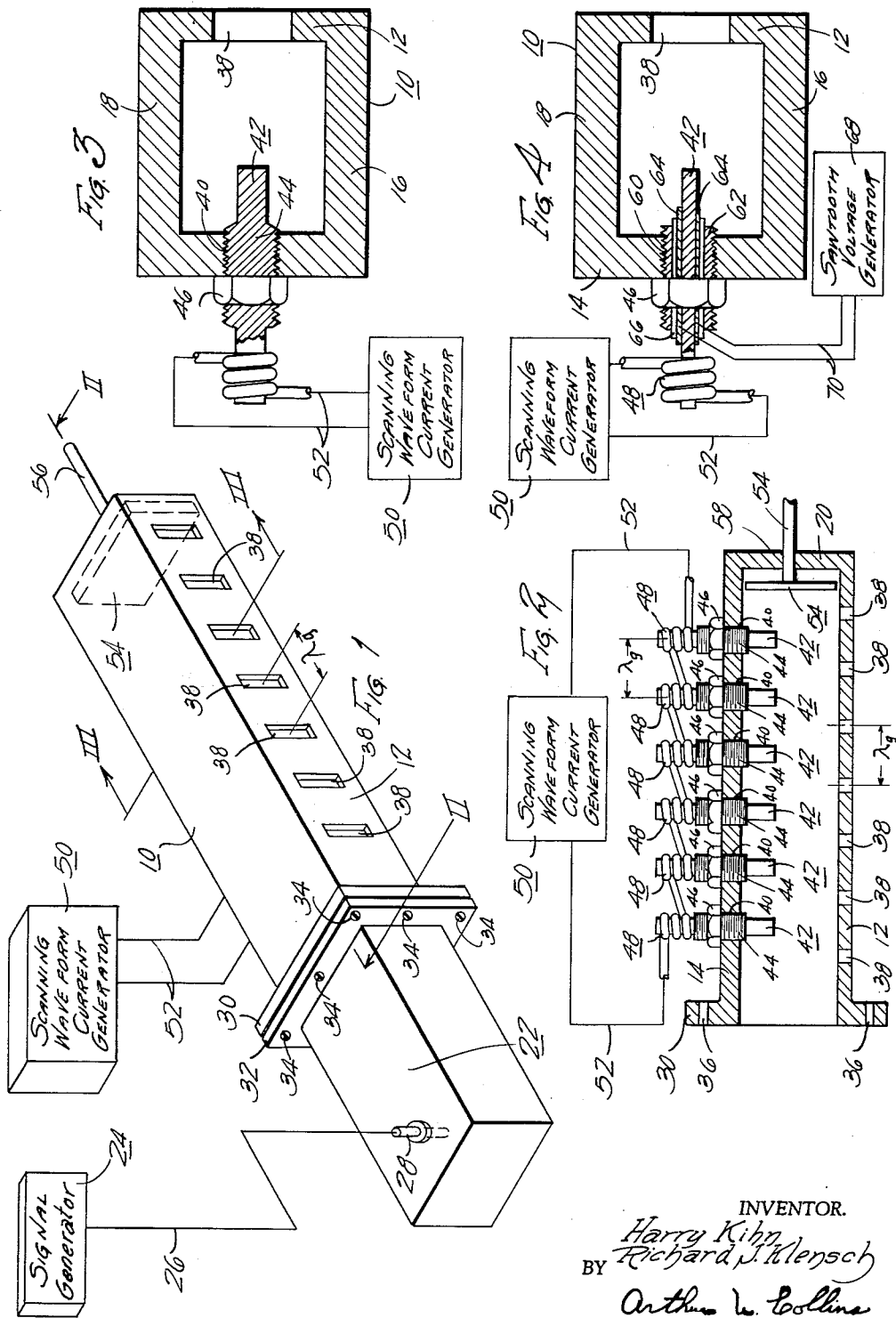
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HIGH-SPEED, NARROW BEAM RADAR SCANNING ANTENNA

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HIGH-SPEED, NARROW BEAM RADAR SCANNING ANTENNA

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This invention relates to antennas and more particularly to radar antennas of the scanning type.

One object of the invention is to control the phase velocity of a wave being propagated in an antenna.

Another object of the invention is to accurately control the beam tilt or scan angle of an antenna.

Another object of the invention is to provide a scanning antenna having a substantially constant input impedance.

In conformity with these objects, the preferred embodiment of the invention is characterized by a substantially rectangular-shaped waveguide having an array of radiating slots in one wall thereof and carrying a plurality of spaced ferrite rods or cores in the opposite wall thereof. The ferrite rods are adjustably connected to the waveguide for movement substantially transversely of the guide and an adjustable coil or the like is carried by the portion of each ferrite rod projecting externally of the waveguide. The coils are energized from a variable amplitude current source and the degree of coupling between the coils and the ferrite rods determines the permeability of the ferrite rods and thus controls the phase velocity of the wave being propagated in the waveguide. By controlling the phase velocity, the beam tilt or scan angle of the antenna can then be accurately predetermined and maintained.

These and other objects of the invention will become readily apparent to those skilled in the art from the following detailed description of two embodiments thereof taken in connection with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a radar antenna illustrating the preferred embodiment of the invention;

FIG. 2 is a transverse longitudinal section taken substantially along the line II-II of FIG. 1;

FIG. 3 is a transverse section taken substantially along the line III-III of FIG. 1; and

FIG. 4 is a transverse section similar to FIG. 3 but showing another embodiment of the invention.

Referring more particularly to the drawings wherein like components are designated by like reference numerals, FIGS. 1, 2 and 3 show the antenna as comprised of a length of hollow waveguide 10 which is substantially rectangular-shaped in transverse cross-section and which is defined by a front wall 12, an opposing rear wall 14, a bottom wall 16, a top wall 18 and a single end wall 20. The end of hollow waveguide 10 opposite the end wall 20 is "open" and communicates or registers with the "open" end of another length or section of hollow waveguide 22. Waveguide section 22 is substantially identical in cross-section or configuration to waveguide 10 and in function serves as a transmission line circuit for energizing or feeding a desired signal to the waveguide 10. The waveguide section 22 is supplied with a desired or predetermined signal by a signal generator 24 which may take the form of a magnetron, a klystron, a duplexer or any other suitable type of signal generating source. The output of the signal generator 24 is supplied to the waveguide section 22 by means of a coaxial transmission line or the like 26 and is fed directly into waveguide section 22 by means of a probe 28 which is carried in one wall

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of the waveguide section and extends substantially transversely thereof. Any suitable type of connection means may be employed to connect the coaxial transmission line 26 to the probe 28 and to connect the probe 28 to the waveguide section 22.

The "open" ends of the waveguide 10 and the waveguide section 22 are provided with opposing flange 30 and 32, respectively, thereon and, in assembly, the opposing flanges 30 and 32 are rigidly connected to maintain a substantial axial alignment between the waveguide 10 and waveguide section 22 and to provide a substantially leak-proof connection therebetween. The opposing flanges 30 and 32 are connected in this particular instance by a plurality of bolts 34 which extend through aligned holes or passages in the opposing flanges, only the passages 36 in the waveguide flange 30 being shown. The waveguide 10 and the waveguide section 22 are both preferably made of a good electrical conductor such as copper or steel and are both dimensioned so that in operation only the dominant TE₁₀ mode or wave with the shortest cutoff wavelength will be propagated therein.

The front wall 12 of the waveguide 10 is provided with an array or plurality of radiating slots or passages 38 therein which are adapted to afford coupling of the energy from within the guide to free space. In this preferred embodiment of the invention, front wall 12 is provided with seven radiating slots 38 therein, although the specific number of slots per se is not critical or of no importance, and the slots 38 extend substantially transversely of the wall. Slots 38 may be of any suitable size depending upon the amount of coupling of energy that is desired and, in this particular instance, the slots 38 are spaced one waveguide wavelength λ_g apart, i.e. one waveguide wavelength as distinguished from the wavelength of the same wave or mode being transmitted in free space.

The rear or opposite wall 14 of waveguide 10 is provided with a plurality of spaced and aligned apertures or passages 40 therein each of which is adapted to receive a ferrite rod means or core 42, preferably made of nickel alloy-ferrite or nickel zinc-ferrite. In this preferred embodiment of the invention, rear wall 14 is provided with six apertures 40 therein, though again the specific number of apertures per se is not critical and of no importance, and the apertures 40 are threaded. Each ferrite rod 42 is in turn provided with a threaded body portion 44 (FIG. 3) intermediate its ends which is adapted to be received in the threaded apertures 40. This threaded connection between the ferrite rods 42 and rear wall 14 thus provides an adjustable connection between the waveguide 10 and the ferrite rods 42 whereby the ferrite rods can be moved in opposite directions substantially transversely of the waveguide. The threaded portion 44 of each ferrite rod 42 projecting externally of guide 10 carries a nut 46 for locking the ferrite rods in any given position of adjustment. It will also be noted in FIG. 2 that the spacing between the ferrite rods is also one waveguide wavelength or λ_g . The threaded passages 40 in this preferred embodiment of the invention are positioned in rear wall 14 such that the ferrite rods 42 are positioned directly between the radiating slots 38, or expressed in another manner, such that the longitudinal axes of the ferrite rods are spaced substantially equidistantly between adjacent radiating slots. It will be appreciated, however, that the ferrite rods 42 need not be so symmetrically positioned with reference to the radiating slots 38 inasmuch as the absence of a symmetrical relationship between the rods and slots can easily be compensated for by merely varying the depth of insertion of the ferrite rods, as will be discussed more in detail hereinafter.

A coil or coil means 48 is carried by each of the ferrite rods 42 externally of the waveguide 10 and a scan-

ning waveform current generator 50 of the variable amplitude type is connected to each of the coils 48 by a pair of leads 52. The coils 48 are preferably connected in series to the scanning waveform current generator and the windings of the coils 48 are adjustably connected to the ferrite rods 42 by any suitable means (not shown) whereby the coupling between each ferrite rod and coil may be selectively varied, the purpose of varying the coupling between the ferrite rods and coils to be discussed more fully hereinafter in connection with the operation of the antenna.

Waveguide 10 also carries a tuning plunger 54 in one end thereof to tune-out any reactive component that may be present in the guide to thereby improve the impedance matching of the guide as a function of frequency. The position of the plunger 54 within the waveguide 10 may be selectively varied by means of a control rod 56 which extends through a passage 58 in waveguide end wall 20 and is connected to the plunger 56 by any suitable means (not shown). Instead of placing a tuning plunger within the waveguide 10, the present invention also contemplates the utilization of a termination resistance or the like in combination with the waveguide. The termination resistance could be placed in one end of the waveguide and preferably should have an impedance equal to the guide impedance. This termination resistance could easily be attached or secured to the inner surface of waveguide end wall 20 and, in function, would serve to prevent any reflection of power from this one end of the waveguide.

In operation, with the ferrite rods 42 inserted into the waveguide 10 and with the coils 48 connected to the scanning waveform current generator 50, a portion of the waveguide-wall-current will be intercepted by the radiating slots 38 and the antenna will produce a substantially broadside, fan-shaped scanning beam (not shown). The total amount of energy radiated from slots 38 and coupled to the atmosphere will of course be the summation of the energy individually radiated from each slot. The spacing between the radiating slots 38, one waveguide wavelength or λ_g , will serve to insure the production of a broadside or fan-shaped beam if the wavelength of the signal being propagated within the guide is kept or maintained at a predetermined value.

If the wavelength of the signal in the guide (λ_g) changes, however, the beam will "tilt" or will not maintain its broadside or normal shape. To prevent "tilting" of the beam, the phase velocity of the wave or mode being propagated within the guide 10 as well as the phase shifts or paths between the radiating slots 38 must be accurately controlled or maintained at a substantially constant predetermined value. With regard to phase velocity, it is well known that the phase velocity β of a wave being propagated within a waveguide is related to the wavelength λ_g of the propagated wave and its frequency f_g by the following formula: $\beta = \lambda_g f_g$. It is also well known that the phase velocity β of the propagated wave may be expressed by the formula $\beta = \sqrt{\mu/\epsilon}$, where μ is the permeability and ϵ is the dielectric constant of the material in the waveguide, the material in the waveguide being in this particular instance the ferrite rods 42. From these formulae, it can thus readily be seen that a change in either μ or ϵ of the ferrite rods 42 will cause the beam to "tilt."

Since the degree of magnetization of each ferrite rod 42 can be selectively varied by adjusting the coupling between each ferrite rod 42 and the coil 48 carried thereby and the degree of magnetization predetermines the permeability of each ferrite rod, the present invention thus provides a means of controlling the phase velocity of the wave being propagated in guide 10 which in turn provides a means of controlling the beam "tilt" or scan angle. The phase shifts between adjacent radiating slots 38 in the guide 10 can also be accurately and individually con-

trolled by varying the depth of insertion of the transversely adjustable ferrite rods 42.

It will also be apparent that varying the coupling between the ferrite rods 42 and the coils 48 by varying the spacing between the coil windings and the rods will insure equal phase shifts per ferrite rod. Varying this magnetic coupling will also serve to control the amount of H field applied to each ferrite rod and thus can be utilized to compensate for minor hysteresis loop differences in the ferrite rods. By maintaining identical phase shifts per ferrite rod throughout the entire scan cycle, beam deterioration will also be kept to a minimum.

An antenna constructed in accordance with the present invention will provide an antenna especially suitable for use on high speed aircraft. Such an antenna is capable of operating effectively in the microwave region and scanning approximately a 30° sector with beam less than 1%.

FIG. 4 shows another embodiment of the antenna which is designed to improve the impedance matching of the waveguide 10 thereof as a function of beam "tilt" or scan angle. It is well known that the waveguide impedance Z is related to μ and ϵ by the formula

$$Z = \sqrt{\frac{\mu}{\epsilon}}$$

where μ is the permeability and ϵ is the dielectric constant of the material within the waveguide, i.e. the dielectric rods. From this formula, it can readily be seen that a change in μ alone will effect the waveguide impedance and thereby make it more difficult for the antenna to accept power from a transmitter or the like. On the other hand, if μ varied as ϵ , the antenna input impedance would remain more nearly constant and the phase shift and thus the scan angle would be increased.

The embodiment of the antenna shown in FIG. 4 achieves a more constant μ/ϵ ratio by covering a portion of the ferrite rods 42 with a voltage sensitive dielectric and applying a sawtooth voltage across the voltage sensitive dielectric in phase with the excitation current supplied to the coil 48 carried by each of the ferrite rods. Structurally, the embodiment of FIG. 4 differs specifically from the preferred embodiment of the invention in that rear wall 14 of waveguide 10 is provided with a plurality of spaced and aligned apertures 60 therein each of which is threaded and adapted to receive an externally threaded tubular sleeve 62. The tubular sleeves 62 in turn carry the ferrite rods 42 with each ferrite rod 42 carrying a pair of elongated and opposed conductors 64—64 which preferably take the form of a pair of diametrically opposed silver strips, the silver strips 64—64 extending beyond the tubular sleeve 62 and into the waveguide 10. Each ferrite rod 42 including the pair of opposed silver strips 64—64 is covered or coated with a voltage sensitive dielectric 66 which preferably takes the form of strontium titanite although other forms of a voltage sensitive dielectric such as barium titanite may be successfully employed. A sawtooth voltage generator 68 is connected to the silver strips 64—64 carried by each ferrite rod 42 by a pair of leads 70 to apply the in phase voltage to thereby produce the more constant μ/ϵ ratio.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

We claim:

1. A radar scanning antenna comprising a substantially rectangular-shaped waveguide having an array of radiating slots in one wall thereof and a plurality of threaded and aligned passages in the opposite wall thereof, a threaded tubular sleeve carried in each of said threaded and aligned passages in said opposite wall, a ferrite core carried in each of said threaded tubular sleeves and being movable with each of said threaded tubular sleeves substantially transversely of said waveguide, a pair of op-

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posed conductors carried by each of said ferrite cores, a voltage sensitive dielectric carried by and completely surrounding each of said ferrite cores intermediate the ends thereof, adjustable coil means carried by each of said ferrite cores externally of said waveguide, a current waveform generator connected to each of said coil means for supplying current to each of said coil means to thereby provide a current waveform necessary to scan said antenna, and a sawtooth voltage source connected to said opposed conductors carried by each of said ferrite coils for applying a sawtooth voltage across said voltage sensitive dielectric in phase with the current supplied to each of said coil means, said applied sawtooth voltage being operable to maintain substantially constant the input impedance of said antenna.

2. A radar antenna as claimed in claim 1 wherein said waveguide is dimensioned to propagate the dominant TE_{10} mode.

3. A radar scanning antenna as claimed in claim 1 wherein said opposed conductors carried by said ferrite cores are comprised of silver strips.

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4. A radar scanning antenna as claimed in claim 1 wherein said voltage sensitive dielectric is comprised of barium titanite.

5. A radar scanning antenna as claimed in claim 1 wherein said radiating slots in said one wall of said waveguide are spaced one waveguide wavelength apart and extend substantially transversely of said one wall.

6. A radar antenna as claimed in claim 1 wherein a tuning plunger is carried in one end of said waveguide.

10 7. A radar antenna as claimed in claim 1 wherein said spaced ferrite cores carried in said threaded tubular sleeves are positioned between said radiating slots such that the longitudinal axes of said ferrite cores are substantially equidistantly spaced from said slots and are spaced
15 substantially one waveguide wavelength apart.

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