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MICROWAVE PROCESS AND APPARATUS

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Fig. 1.

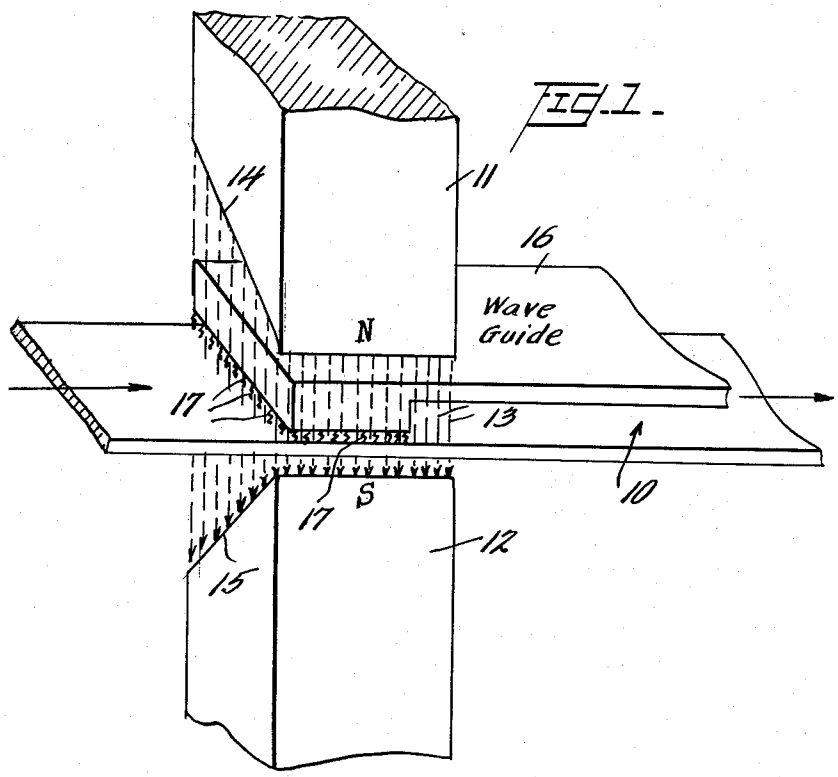
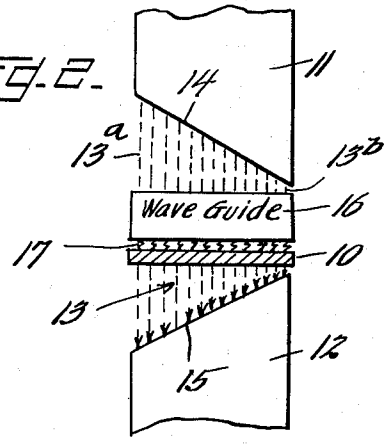


Fig. 2.



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MICROWAVE PROCESS AND APPARATUS

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5 Claims. (Cl. 346—74)

This invention generally relates to improvements in ferromagnetic recording of microwaves and is particularly concerned with the spectral recording of microwaves in both the space and time domains.

It is known that microwave radio beams and even higher frequency radio waves may be magnetically recorded and stored by a process involving premagnetizing certain ferromagnetic materials, such as ferrites, by means of a strong static magnetic field having an intensity related to the frequency to be recorded by the Zeeman energy relationship. After sensitizing the ferromagnetic material in this manner, the material is then subjected directly to the radiated microwave having a magnetic or H component polarized at right angles to the static field, whereby the intelligence in the wave is recorded by varying the magnetized condition of the ferromagnetic material.

Although the interaction phenomena between the static field, microwave, and ferromagnetic material is rather complex and difficult to explain in a nonrigorous manner, one general explanation that may aid in an understanding of this process is that the magnetic dipoles in the material are "tuned" to the frequency of the wave and polarized by the static magnetic field whereby the microwave to be recorded exerts a torque on the dipoles to reorient the spin axes thereof and vary the magnetized condition of that area of the material exposed to the wave. The extent of this reorientation or the number of dipoles whose axes are displaced, is related to the intensity of the microwave whereby an intelligence modulated wave may be recorded as different magnetic intensities in the material. In carrying out the process the ferromagnetic material may be disposed on a tape or other elongated record member, and the member moved lengthwise past the microwave to be recorded in a manner similar to conventional recording at low frequencies to provide a series of intensity modulated magnetic images variable along the length of the record according to the intelligence. For a more rigorous explanation of this phenomena, reference is made to articles entitled "The Nonlinear Behavior of Ferrites at High Microwave Signal Levels" by Harry Suhl, published in the Proceedings IRE, vol. 44, No. 10, page 1270, October 1956, "Radiation Magnetization" by C. H. Becker, published in Zeitschrift für Physik, Bd. 148, pages 391–401, and dated in 1957, and "Magnetic Resonance in Ferrites" by Nicolas Bloembergen, published in the Proceedings IRE, vol. 44, No. 10, page 1259, dated October 1956.

According to the present invention, there is provided an improvement in this process wherein the magnetic recording is not only intensity modulated according to the intelligence of the signal but, in addition, the magnetic recording is also made in the space or frequency domain with the various component frequencies contained in the microwave being recorded at different positions along the record, thereby providing a spectral frequency image of

the signal. More specifically, in the prior art process as above described, the magnetic recording is performed exclusively in the time domain, as in conventional low frequency recording, with the degree of or intensity of magnetization along the length of the moving record being variable according to the time variations in amplitude of the microwave. In the present invention, on the other hand, the modulated microwave to be recorded may be considered in the Fourier analysis manner as the sum of a series of different frequency components, including the fundamental or carrier frequency wave together with the different frequency sidebands thereof. By recording these frequency components in the space domain, or otherwise stated in the frequency domain, these different frequency components making up the waveform are individually captured or imaged at different spatial positions on the record whereby, for example, the carrier frequency component is recorded at the center of the record and the upper and lower frequency sidebands thereof are recorded near opposite sides of the record. The relative amplitudes of these different frequency components of the wave are also magnetically distinguishable from one another on the record since the number of spin states reoriented at each position on the record are proportional to the amplitude of that component of frequency affecting that position on the record.

As in the prior art processes, the ferromagnetic material may also be coated on or embedded in an elongated tape or other suitable carrier that is movable past the electromagnetic wave, thereby enabling a time series of spectral images of the high frequency wave to be captured along the length of the record.

It is accordingly a principal object of the invention to provide a process for ferromagnetically recording microwaves in the space or frequency domain.

A further object is to directly record such waves without a magnetic transducer.

A still further object is to provide such a process wherein the spectral frequency components of a microwave are recorded at variable intensities according to the relative amplitudes of such components.

Still another object is to provide such a process wherein a series of magnetic recordings or images of the microwave may be made in time sequence.

Other objects and additional advantages will be more readily comprehended by those skilled in the art after a detailed consideration of the following specification taken with the accompanying drawings wherein:

FIG. 1 is a perspective view illustrating one manner of practicing the recording process according to the invention, and

FIG. 2 is a cross sectional view observed from the left hand side in FIG. 1.

Referring now to the drawings for a consideration of one process for applying the invention, there is shown in FIGS. 1 and 2, an elongated tape **10** or other record member being comprised of a suitable base having coated or impregnated therein a suitable ferromagnetic material, such as one of the known ferrite compositions commonly employed for binary magnetic memory devices in electronic computers. The record member **10** is positioned between a pair of opposite polarity magnet poles **11** and **12** and may be suitably guided and provided with drive

means (not shown) for movement lengthwise between the pole pieces **11** and **12**. The magnetic poles **11** and **12** may be either portions of a strong permanent magnet structure or a suitable electromagnet, in either case the magnet being capable of producing a strong static magnetic field **13** through the tape **10** to premagnetize the ferrite material.

As best shown in FIG. 2, the pole faces **14** and **15** are uniformly inclined away from each other to provide a progressively increasing air gap between the poles **11** and **12** from right to left transversely across the tape **10**. As a result, the magnetic field or flux **13** between the poles **11** and **12** and passing through the tape **10**, progressively decreases in intensity across the tape with the concentration of flux at the right side in FIG. 2, and represented by the lines numbered **13***b*, being far greater than the flux density **13***a* at the left side of the tape, and with the intermediate portions across the tape receiving a progressively less intense magnetic field from right to left.

As generally discussed above, the static magnetic field **13** serves to premagnetize or "tune" the magnetic dipoles in the ferromagnetic material, conditioning these dipoles to respond to a high frequency electromagnetic wave having a magnetic or H component disposed at right angles to the static field **13**. The relationship between the resonant frequency response of the dipoles and the static magnetic field is known to be linear according to the Zeeman energy relationship. Consequently, those portions at the right hand side of the tape **10** in FIG. 2, that are energized by the most intense magnetic field **13***b*, are tuned to respond to a much higher frequency wave than those at the left hand side of the tape **10** and the regions therebetween extending from right to left across the tape are progressively tuned to resonate at microwave frequencies between the higher and lower frequency.

The electromagnetic wave **17** to be imaged or recorded on the tape **10** is polarized to excite the tape in such manner that the H or magnetic component thereof is at right angles to the static field **13**. This polarized electromagnetic wave **17** may be conveyed through a suitably positioned waveguide **16** as shown, that is properly designed to transmit the microwave in the correct mode desired to excite the tape **10**.

Due to the fact that the surface of the tape **10** is not equally premagnetized in a direction transversely thereacross, the different positions or regions across the tape are tuned to resonate at different frequency radio waves, and consequently a radio wave at one given frequency within the tuned range will be recorded at only one transverse region on the tape that is "tuned" to resonate at that frequency. Similarly, a radio wave at a second frequency will be recorded at a different transverse region on the tape. Consequently, the various frequency sideband components being contained in an intelligence modulated radio wave **17** will be recorded in a spatially dispersed pattern across the record, to capture a spectral magnetic image of the radio beam transversely across the tape.

As generally mentioned above, the recording phenomena results from the fact that the microwave **17** interacts with the static magnetic field **13** to produce a torque on the magnetic dipoles in the ferromagnetic material, thereby to reorient the axes thereof and produce a measurable magnetic change in the material in the regions of the tape affected. The extent of this change or the degree of magnetization being produced at each transverse position is proportional to the strength or intensity of that frequency component of the microwave **17**. Therefore, the relative amplitudes of the spectral components being recorded at different positions are distinguishable from one another by the relative intensity of the magnetic change produced at each different region on the record. In other words, the different component frequencies in the radio wave are magnetically recorded in a spectral or spatial distribution transversely across the tape **10** with each frequency component producing a magnetic intensity change in the record material corresponding to the relative amplitude of that frequency component in the wave.

Although but one preferred process for carrying out the invention has been illustrated and described, it is believed evident that many changes may be made by those skilled in the art without departing from the spirit and scope of the invention. For example, the record member **10** may be in the form of a drum, sphere, or in any other shape or size desired according to the application of the process. Similarly, the microwave **17** to be recorded may be obtained and focussed in any known manner without the need for a specific wave guide structure **16** or other specific type conveying means. The static magnetic field **13** may be produced by permanent magnets or electromagnets having any desired pole face configuration or in other known manner to provide any desired nonhomogenous static magnetic field pattern transversely across or lengthwise along the record member, as is desired. Consequently, according to the present invention, the ferromagnetic record may be premagnetized in any uniform or non-uniform spatial pattern as desired to spectrally record the intelligence in any desired spatial code as controlled by the static magnetic field pattern energizing the ferromagnetic material.

Since these and many other changes may be made, this invention is to be considered as being limited only according to the following claims appended hereto.

What is claimed is:

1. A process for magnetically recording a spectrum of the component frequencies of a microwave frequency field on a ferromagnetic member comprising the steps of: producing a spatially variable static magnetic field with the intensities of the field at different positions in space being related to the component frequencies to be recorded by the Zeeman energy relationship, subjecting a region of the ferromagnetic material to the field thereby to premagnetize different positions on the material to different magnetic intensities, and directing the microwave field to be recorded simultaneously over the region of the ferromagnetic material subjected to the static field, with the H component of the microwave field being transverse to the static magnetic field.

2. A process for magnetically recording the integral frequency components of a microwave frequency field at different spatial positions on an elongated ferromagnetic material comprising the steps of: producing a nonuniform magnetic field in space in the pattern desired, subjecting a region of the ferromagnetic material to the nonuniform field with different spaced areas of the ferromagnetic material being subjected to different intensities of the magnetic field, and directing a microwave frequency intelligence modulated signal to simultaneously excite an extended region of the ferromagnetic material with the wave being polarized so that the H vector thereof is transverse to the nonuniform magnetic field.

3. A process for magnetically recording simultaneously the integral components of a high frequency electromagnetic wave at different positions along an extended region of ferromagnetic material, comprising the steps of: nonuniformly premagnetizing an extended region of the ferromagnetic material, with the intensity of the premagnetizations at different spaced positions in the region being different and related to the frequency component to be recorded at that position by the Zeeman energy relationship, and simultaneously exposing the extended region of the premagnetized material to the wave to be recorded that is polarized in such direction that the H vector thereof is transverse to the static magnetic field at each different position in the region.

4. A process for magnetically recording a frequency spectrum of the integral components of a high frequency electromagnetic field along an extended region of ferromagnetic material comprising the steps of: producing a nonuniform static magnetic field along the region of the

material with the intensity of the static magnetic field progressively varying in space in a uniform manner from position to position across the region and with the intensity of the static magnetic field at the different positions in the region being related to the frequency component to be recorded at that position by the Zeeman energy relationship, and simultaneously exposing the extended region of the material to the field to be recorded, which microwave is polarized in such manner that the H vector thereof is transverse to the static magnetic field at each different position across the region.

5. A process for directly recording microwave radio beams comprising the steps of: dispersing a ferromagnetic material along an extended surface, tuning said material

to a range of microwave frequencies that it is desired to record by energizing said surface with a static magnetic field of nonuniform intensity over said surface related to the range of frequencies to be recorded by the Zeeman energy relationship, and simultaneously exciting said surface with a polarized beam of the microwave to be recorded with the H vector of the beam being transverse to the static field.

References Cited in the file of this patent

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