Sept. 13, 1966 W. FISHBEIN 3,273,144

NARROW BEAM ANTENNA SYSTEM

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FIG. 1

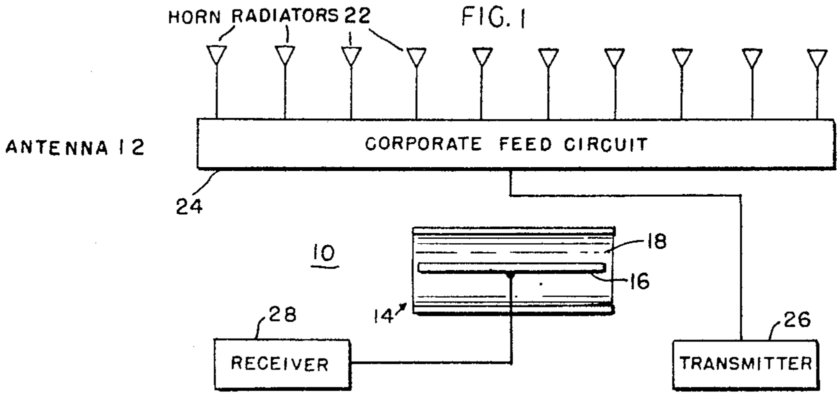

FIG. 2

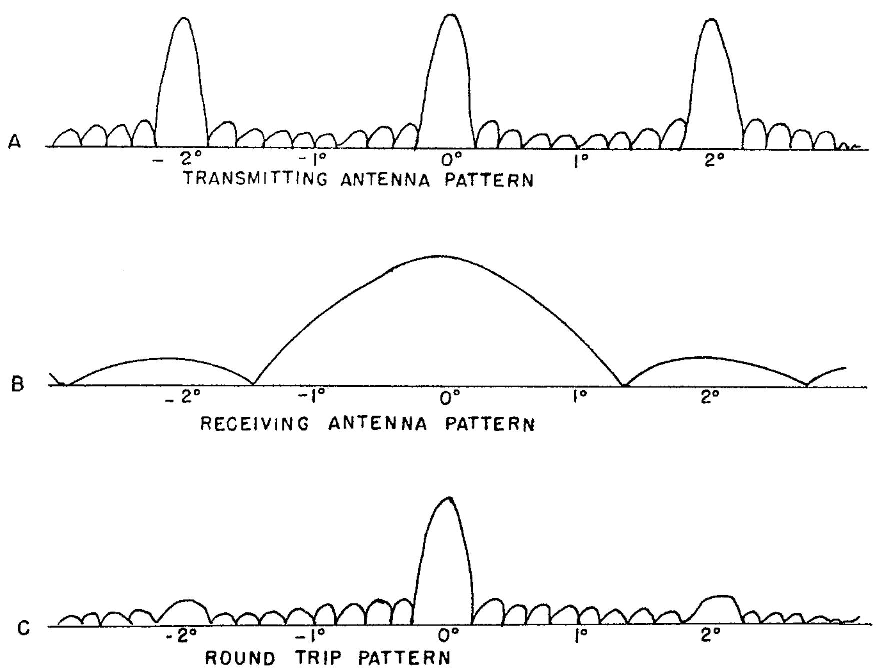

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FIG. 3

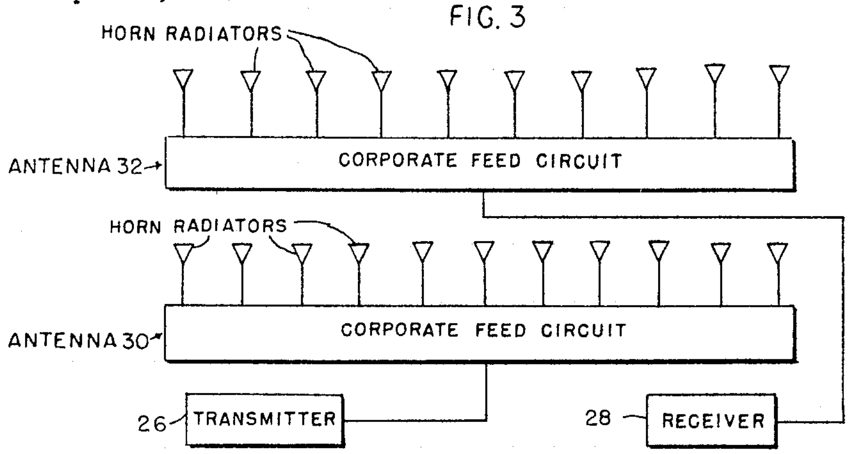


FIG. 4

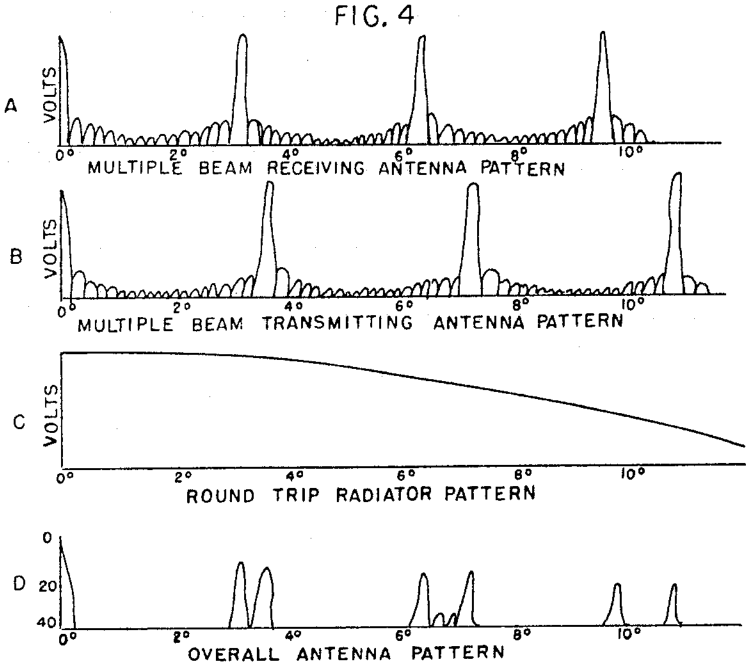
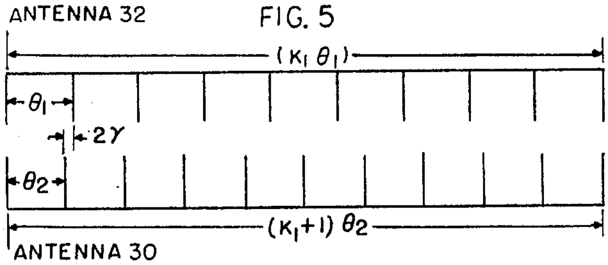


FIG. 5



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NARROW BEAM ANTENNA SYSTEM

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3 Claims. (Cl. 343—5)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to a radar antenna system and more particularly to multiple-beam antenna systems having improved resolution without increasing the number of radiating elements of the antenna structure.

Radar resolution applies to the ability of a radar apparatus to distinguish between two closely situated targets. Heretofore, the solution for the problem of increasing resolution most commonly adopted by the art was to increase the number of radiating elements of the antenna structure. The increased number of radiators, of course, made such antennas difficult to construct, too difficult to scan, and have proved to be too cumbersome to be properly handled. In battlefield application, in particularly, the antenna sizes are limited by tactical consideration. One approach to overcome this problem resides in the use of relatively short wavelengths. However, it is well known that as the frequency of a radar increases, the available transmitter power and receiver sensitivity rapidly decrease. The result of this decrease in transmitter power and receiver sensitivity is poor range performance.

The radiation or field strength pattern usually associated with radar apparatus are characterized by a single major radiation lobe whose ability to resolve between distant targets is a function of the size and the number of radiators of the antenna. Antenna configurations exhibiting narrow beam width in proportion to their size and number of radiators as compared with the more widely used radar antenna types are equally unsatisfactory because their field strength patterns are composed of a plurality of narrow lobes. The difficulty with such a plurality of narrow lobes resides in the fact that, while capable of ample resolution, their usefulness for radar purposes is destroyed because there is no way to distinguish between the directivity of the different lobes when targets are detected.

It is an object of the present invention to provide a new and improved antenna system which avoids one or more of the limitations and disadvantages of prior antenna systems.

It is another object of the invention to provide a narrow beam antenna, which is relatively light in weight, can be easily scanned and is relatively easy to construct.

In accordance with one embodiment of the invention there is provided a radar antenna system providing improved resolution which includes discrete transmitter and receiver antennas. The transmitter antenna, which radiates R–F signal energy, has a directivity characteristic including a plurality of angularly spaced main lobes. The receiver antenna intercepts reflections of the radiated R–F signal energy and has a directivity characteristic including a single major lobe which is in the same direction as a selected one of the plurality of the spaced main transmitter antenna lobes. The beam width of the single lobe is such that it can detect signals derived from only one of the lobes of the transmitter antenna.

In accordance with another embodiment of the invention, the discrete transmitter and receiver antennas are both of the multiple-beam type, and each having approximately the same directivity characteristic. The angular lobe spacing in one antenna with respect to the

other is such that, over a prescribed angular sector, if one pair of transmitting and receiving lobes are made to coincide, the others will not coincide.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings in which:

FIG. 1 illustrates one embodiment of a radar antenna system in accordance with my invention;

FIG. 2 illustrates curves useful in explaining the operation of the FIG. 1 embodiment;

FIG. 3 represents a second embodiment of the radar antenna system; and

FIGS. 4 and 5 illustrate curves useful in explaining the operation of the FIG. 3 embodiment.

Referring now to FIG. 1 of the drawing, at **10** there is shown an improved antenna system for a radar. The radar antenna system comprises a multiple-beam type transmitting antenna **12** and a receiving antenna **14**. Multiple-beam antenna **12** comprises a linear array of a prescribed number of spaced waveguide horn radiators, and radiates the R–F energy in a pattern comprised of a plurality of angularly spaced main lobes. The number of lobes will, of course, depend upon the number of radiators provided, and the spacing between lobes and the beam width of the lobes will depend upon the spacing between radiators and the aperture width. The receiving antenna **14** includes a receiving element **16** and a reflecting surface **18**. The shape of reflecting surface **18** and receiving element **16** may be constructed in any one of several conventional shapes, the parabolic cylinder and line source, respectively, being represented in FIG. 1. The beam width of the receiving lobe pattern is chosen such that it can pick out any reflected signal derived from a selected one of the lobes of the multi-beam transmitter antenna pattern, while the remaining transmitter antenna lobes fall outside the main lobe of the receiver antenna beam and, consequently, are reduced by the side lobe level of the receiver antenna beam. In one embodiment of my invention, for operation at a wavelength of 1.86 centimeters, for example, transmitting antenna **12** comprised ten linearly aligned horn radiators **22**, each with a 20 db gain and spaced 30 wavelengths apart. These radiators are fed in phase by means of a conventional corporate feed structure represented by the block **24** so that there is produced a uniform phase front over a 500 megacycle frequency band. It is to be understood, of course, that any other suitable feeding circuit may be used to provide the uniform phase front. The blocks **26** and **28** comprise the transmitter and receiver of the radar and are conventional. With the arrangement hereinabove described, the resulting transmitted antenna pattern will be approximately as shown in FIG. 2A. Every two degrees there is a main lobe 0.16 degree wide. As shown in FIG. 2B the receiving antenna **14** has a beam width of about 1.5 degrees so that it can pick out any selected one of the 0.16 degree main lobes of the transmitter antenna pattern. The round trip antenna pattern is shown in FIG. 2C. It can be seen in FIG. 2C that the remaining transmitting lobes fall outside the main lobe of the receiver antenna beam and are reduced by the side lobe level thereof. Scanning the multiple-beam transmitting antenna **12** may be accomplished by rotating the pedestal it is mounted on or by employing phase shifters in the lines that feed the horn radiators. Mechanical or ferrite phase shifters may be used. The scan angle, of course, is limited to the beam width of the individual horns. With such an arrangement, the system may be programmed by rotating only the receiver antenna **14** in synchronism with the amount of phase shift.

FIG. 3 illustrates another embodiment of my invention. In FIG. 3, the transmitting and receiving antennas **30** and **32** are both of the multiple-beam type and each comprise a linear array of waveguide horns fed by appropriate respective corporate feed structures. Both antennas are arranged to provide multiple lobe patterns. However, the wavelength spacing between the radiators in multiple-beam transmitting antenna **30** is made different than the wavelength spacing between the radiators in multiple-beam receiving antenna **32**. The lobe spacing in both antennas is chosen such that if one pair of transmitter and receiver antenna lobes are made to coincide, the others will not coincide over the angular sector of interest. For example, should the radiator element spacing of transmitter multi-beam antenna **30** be 18 wavelengths, the lobes will be spaced by 3.15 degrees. A radiator element spacing of 16 wavelengths for the receiver multi-beam antenna **32** will result in a lobe spacing of 3.50 degrees. Thus, when the orientation of the respective antennas is such that the broadside lobes coincide, there will not be an overlap until approximately 32 degrees have passed. If the individual radiators have a 20 degree beamwidth, the second overlap will be in the side lobes of the transmitted radiator pattern. The round trip pattern will thus have only one lobe. Assuming that the individual radiator elements are considered as being isotropic radiators, and are uniformly illuminated, FIGS. 4A and 4B show the calculated patterns for the multiple-beam receiving and transmitting antennas **32** and **30**, respectivley. FIG. 4C shows the round trip pattern of an individual radiator. FIGURE 4D is the pattern resulting from the multiplication, in space, of the patterns shown in FIGS. 4A, 4B and 4C, and illustrated a coincidence at 0°. The only lobes plotted are those greater than 40 db below the main lobe. It should be noted that there is one main lobe, with secondary lobes at least 14 db down. The 14 db secondary lobe level is a result of the assumption of uniform illumination of the individual horn antennas. A tapered illumination would result in a secondary lobe level of 20 db to 25 db.

The two horn antennas **30** and **32** of FIG. 3 could be easily scanned in synchronism by using phase shifters in the feed lines to the individual radiators. A 20 degree sector could be mechanically scanned without moving either antenna more than 3.5 degrees from its initial position. The scanning sequence is as follows: Both antennas face broadside, which causes the broadside lobes to coincide. The two antennas scan in synchronism for 3.15 degrees. The antennas are returned to the broadside position. The antenna with the lobe spacing of 3.50 degrees is then indexed 0.35 degree with respect to the second antenna. This indexing causes the lobes which are 3.15 degrees from broadside to coincide. Both antennas now scan in synchronism for 3.15 degrees, thus covering the second 3.15 degree sector. The antennas are again returned to the broadside position. The transmitting antenna is indexed an additional 0.35 degree with respect to the receiving antenna. Now the lobes which are 6.3 degrees from broadside coincide. The process is repeated until the entire 20 degree sector has been scanned.

The optimum spacing of the receiver and transmitter radiator elements can be determined by the following analysis and reference to FIG. 5.

n_1=radiator wavelength spacing of receiver antenna **32**,
n_2=radiator wavelength spacing of transmitter antenna **30**,

where $n_1 < n_2$,

γ=beamwidth of each antenna array in radians,
β=beamwidth of individual radiators in the array in radians.

The values of n_1 and n_2 must be chosen to satisfy two conditions. First, if the two lobes of a pair are made to coincide, the second coincidence must occur in the

side lobe region of the pattern of an individual radiator. That is to say, if the first coincidence is made to occur at the 3 db point of the radiator pattern, the second coincidence should not occur until angle 1.5β has passed. Second, the minimum spacing between pairs of lobes should be twice the array beam width. If both these conditions are satisfied, there will be only one main lobe in the round trip pattern. FIG. 5 shows the relative positions of the lobes of the two antennas shown in FIG. 3 when both conditions are satisfied. It is to be understood, of course, that the antennas **30** and **32** could readily be interchanged, that is, antenna **30** could be the receiving antenna and antenna **32** could be the transmitting antenna, and the systems would operate in the same manner.

Now, as shown in FIG. 5, the spacing between lobes of antenna **32** is given by

$$\theta_1 = \frac{1}{n_1} \qquad (1)$$

and the spacing between lobes of antenna **30** is given by

$$\theta_2 = \frac{1}{n_2} \qquad (2)$$

Assuming K_1 lobes of antenna **32** before second coincidence, then

$$1.5\beta = K_1\theta_1 = \frac{K_1}{n_1} \qquad (3)$$

Hence, there will be K_1+1 lobes of antenna **30** before the second coincidence and thus

$$1.5\beta = (K_1+1)\theta_2 = \frac{K_1+1}{n_2} \qquad (4)$$

In order to satisfy the second condition hereinabove described,

$$\theta_1 - \theta_2 = 2\gamma \qquad (5)$$

or

$$\frac{1}{n_1} - \frac{1}{n_2} = 2\gamma \qquad (6)$$

The following relationship between n_1 and n_2 may be obtained from Equations 3 and 4

$$1.5\beta = \frac{1.5\beta n_1 + 1}{n_2} \qquad (7)$$

so that

$$n_1 = \frac{1.5\beta n_2 - 1}{1.5\beta} = n_2 - \frac{1}{1.5\beta} \qquad (8)$$

From Equation 6

$$n_2 - n_1 = 2\gamma n_1 n_2 \qquad (9)$$

and using the value of n_1 from Equation 8 we have

$$n_2 - n_2 + \frac{1}{1.5\beta} = 2\gamma n_2\left(n_2 - \frac{1}{1.5\beta}\right) \qquad (10)$$

or

$$2\gamma n_2(1.5\beta n_2 - 1) = 1 \qquad (11)$$

Since, in general, $1.5\beta n_2 >> 1$, Equation 10 can be simplified to

$$3\gamma\beta n_2^2 = 1 \qquad (12)$$

or

$$n_2 = \frac{1}{\sqrt{3\gamma\beta}} \qquad (13)$$

and from Equation 8

$$n_1 = n_2 - \frac{1}{1.5\beta} \qquad (14)$$

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is therefore aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A radar antenna system providing improved resolution comprising, a first multiple-beam antenna for radiating R-F signal energy, said first antenna having a directivity characteristic of a plurality of angularly spaced lobes, a second multiple-beam antenna for intercepting reflections of the radiated R-F signal energy, said second antenna having a directivity characteristic of a plurality of angularly spaced lobes in substantially the same direction as the lobes of said first antenna, the lobe spacing in one antenna with respect to the other being such that over a prescribed angular sector if one pair of transmitting and receiving lobes are made to coincide, the others will not coincide.

2. The radar antenna system in accordance with claim 1 wherein the beam width of the individual lobes in said first and second antennas are identical.

3. The system in accordance with claim **2** wherein the lobe spacing of said first and second multiple-beam antennas are related such that

$$n_1 = n_2 - \frac{1}{1.5\beta}$$

where

n_1 is the wavelength spacing between radiators in said first antenna,

n_2 is the wavelength spacing between radiators in said second antenna, and β is the beam width of the individual radiators in said first and second antennas.

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