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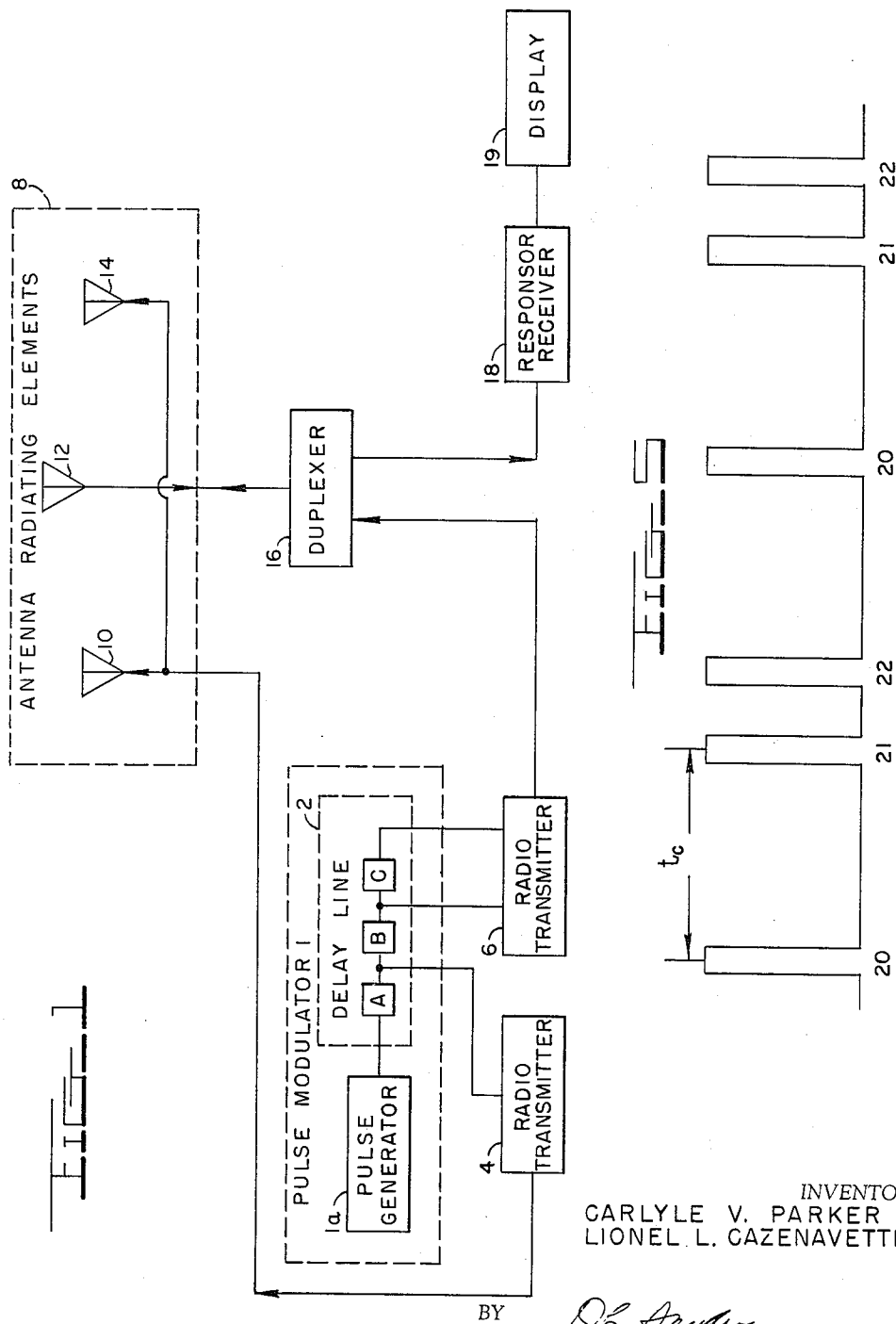
C. V. PARKER ET AL

2,741,759

ARTIFICIAL ANTENNA BEAM SHARPENING SYSTEM

Filed Oct. 14, 1952

3 Sheets-Sheet 1



INVENTORS
CARLYLE V. PARKER
LIONEL L. CAZENAVETTE

BY *P. L. Snyder*
Edward White

ATTORNEY

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3 Sheets-Sheet 2

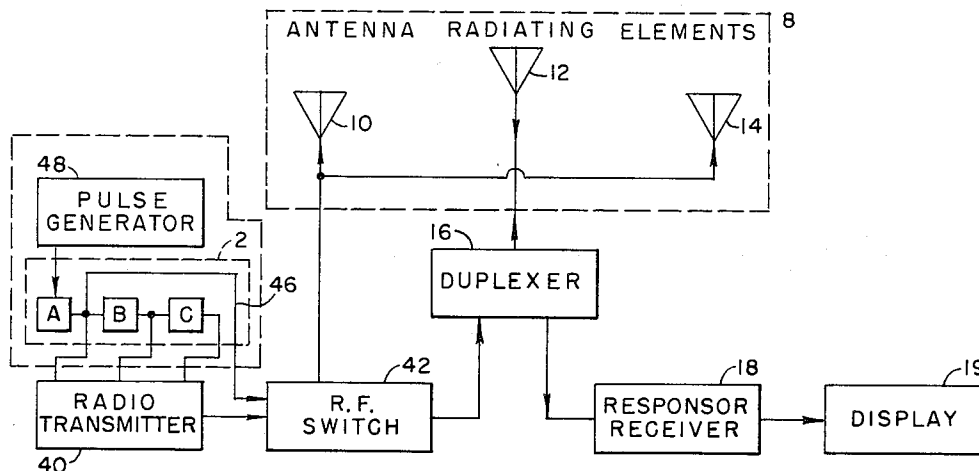
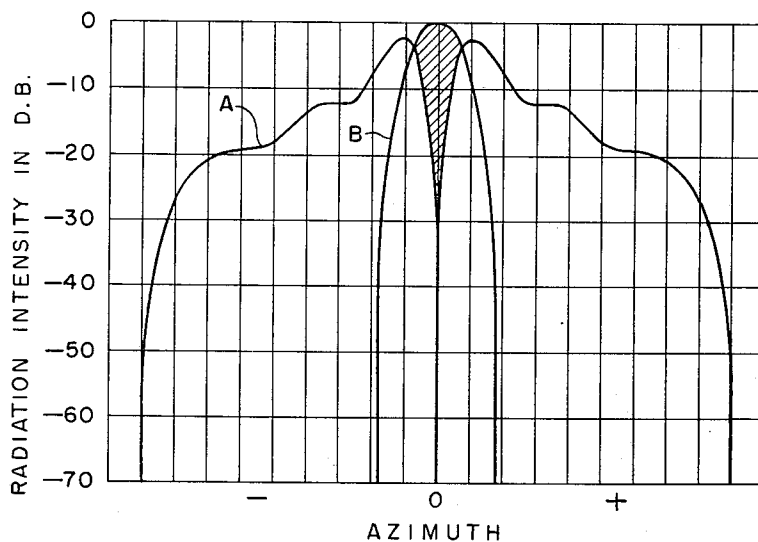


FIG. 3

FIG. 4



INVENTORS
CARLYLE V. PARKER
LIONEL L. CAZENAVETTE

BY

D.B. Apple
Edward White

ATTORNEY

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ARTIFICIAL ANTENNA BEAM SHARPENING SYSTEM

Carlyle V. Parker, Fairfax County, Va., and Lionel L. Cazenavette, New Orleans, La.

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(Granted under Title 35, U. S. Code (1952), sec. 266)

This invention relates to interrogator transponder type electronic recognition systems and more particularly to improvement of the azimuth and elevation discrimination of such systems.

Interrogator-responder-transponder or IFF type electronic identification systems used in conjunction with radar sets generally suffer from poor azimuth discrimination in comparison to that of the associated radar. As cogently presented in Patent No. 2,537,102 granted to Irving Stokes, this is a highly undesirable situation as it becomes very difficult, if not impossible, to determine which craft are friendly in a group of craft having approximately the same range and falling within the arc defined by the segment of space occupied by the interrogating beam. The use of higher frequencies would improve the discrimination of an antenna of a given size, inasmuch as the directivity pattern becomes narrower for a given size of antenna with increase of the operating frequency of the system utilizing the antenna. However, attenuation of signals in the microwave region due to the moisture content of the air becomes more pronounced with increase of frequency. Likewise, the effect of variations in the moisture content of the air becomes more pronounced at higher frequencies. Reliability of operation under all weather conditions is a necessary attribute of an electronic identification system, so it can be seen that it is undesirable to resort to the use of extremely high operating frequencies to improve the azimuth discrimination of such systems.

The use of larger antenna would also improve discrimination at a given operating frequency. However, on shipboard or aircraft installations space is usually at a premium, so large antennae generally are not desirable.

Accordingly, one object of this invention is to improve the azimuth discrimination of an electronic identification system so that it will be as good as, or better than that of the associated radar.

Another object of this invention is to improve the discrimination of an electronic identification system without resorting to extremely high frequencies or to increased antenna size.

A still further object is to provide such an identification system capable of reliable operation under all weather conditions.

Other objects and features of the present invention will become apparent upon consideration of the following detailed description in connection with the accompanying drawings which illustrate various embodiments of the invention. It is to be expressly understood, however, that the drawings are designed for purposes of illustration only and not as a definition of the limits of the invention, references for the latter purpose being had to the appended claims.

Figures 1 and 3 present block diagrams of two typical embodiments of the interrogator-responder systems used in applicant's invention.

Figure 2 shows an embodiment of a transponder system suitable for use with applicant's invention.

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Figure 4 represents idealized radiation patterns of the interrogator antenna as used in applicant's invention.

Figure 5 shows a typical interrogation pulse code used with applicant's system.

The interrogation system described herein is based on the use of a multiple lobe antenna system in which an interrogation pulse signal is transmitted on one radiation pattern and a "lockout" or reply squelch signal is transmitted on a second radiation pattern azimuthal related to the first pattern. Specifically, the "lockout" pulse signal is transmitted in a radiation pattern having a deep null in a given direction, and the coded interrogator pulses are transmitted in a pattern having maximum radiation in the direction of the null of the first pattern. The function of the "lockout" pulse is to prevent a transponder unit located at a distance from the interrogator from responding to the coded interrogation pulses, except when the interrogator pulses are being received with maximum intensity at the transponder.

The transponder can respond only when the "lockout" pulse is of insufficient strength to prevent response; i. e., in the direction of the null. By combining the radiation patterns so that the null in the radiation pattern of the "lockout" pulse corresponds with the direction of maximum radiation of the coded interrogator pulses, as shown in Figure 4 (where pattern "B" represents the interrogator pattern and pattern "A" the "lockout" pulse pattern), an interrogation system having high azimuthal discrimination is made possible.

In conjunction with the interrogation system a remote transponder is used that responds only to coded interrogation pulses of a predetermined characteristic that either are not accompanied by a "lockout" pulse or are accompanied by a "lockout" pulse of less than a given signal strength. The ordinary transponder used in IFF systems transmits a reply radio frequency signal back to the interrogator-responder unit whenever coded pulses of a given characteristic are received by the transponder. By designing the transponder so that it cannot respond to said coded pulses when they are accompanied by a "lockout" pulse above a given signal strength relative to the signal strength of the coded interrogator pulses, it is possible to obtain very narrow angles of response whenever the transponder is used in conjunction with the interrogator and antenna systems previously described. For example, if the transponder will not respond to an interrogation signal if the signal strength of the received "lockout" pulse is above that of the coded pulse, then responses will occur to coded pulses only over the angle defined by the shaded area of Figure 4. As can be readily perceived, this effectively results in sharpening in the angle of response.

The angle over which responses will occur can be varied in several ways. For example, the amount of power in the "lockout" pulse relative to that radiated by the coded interrogator pulses can be increased or decreased. Increasing the amount of power in the "lockout" pulse will result in a narrowing of the angle of response, and decreasing the power will result in a widening of the angle of response. At the transponder end this adjustment can be affected very simply in a manner that will be described in detail.

In Figures 1 and 2 are depicted block schematic diagrams of one embodiment of the invention. Figure 1 shows an interrogator-responder unit in which separate radio frequency transmitters 4 and 6 are utilized to energize the antenna elements radiating according to the nulled pattern "A" and the beam pattern "B" of Figure 4. Radio frequency transmitter 4 is the "lockout" transmitter and is connected to radiating element sections 10 and 14 of antenna 8. Radiating element sections 10 and 14 for example are the halves of a conventional directional radi-

ing system in which radiating elements 14 are energized 180° out of phase with respect to radiating elements 10 in order to provide a directional null pattern such as "A" in Figure 4. In addition to radiating elements 10 and 14, a tertiary radiating element 12 is included in antenna 8 and connected through a conventional duplexer 16 to interrogation transmitter 6 to provide the beamed interrogation pattern whose axis of maximum directivity coincides with the null of the pattern produced by antenna 10 or 14. To provide for suitable interrogator pulse coding and synchronous operation of the "lockout" pulse generator 4, an interrogator pulse modulator such as 1 is added and operated to periodically trigger into operation transmitters 4 and 6 so that transmitter 4 will produce a "lockout" signal and transmitter 6 will produce the desired coded interrogation signals. For example, the pulse train produced by transmitters 4 and 6 may be in accordance with pulse groups such as shown in Figure 5. It may be noted at this point that in Figure 5, pulses 20 are the "lockout" pulses followed in time t_0 by a pair of predetermined time spaced interrogator pulses 21 and 22. It can be readily seen that by this arrangement "lockout" pulses 20 will be emitted according to a null radiation pattern "A" and coded interrogator pulses 21 and 22 necessary to actuate a transponder unit will be emitted according to a beamed signal "B." To obtain such a pulse pattern, any number of suitable conventional pulse modulators may be used. For example, as shown in Figure 1 the modulator 1 may comprise a suitable recurrent pulse regenerator 1a the output of which is fed through a multitapped delay line 2 to the "lockout" pulse transmitter 4 and interrogator transmitter 6. With this arrangement section A provides the first output pulse 20 for operation of transmitter 4 and sections B and C provide the connections for providing the delayed pulses 21 and 22 by interrogator transmitter 6.

In conjunction with the interrogator unit that has been described, it is necessary to provide a specially designed transponder unit which is adapted to be keyed upon the receipt of the time spaced pulses 21 and 22. Such a unit is shown in block diagram form in Figure 2. This transponder is similar to the conventional transponders except for the addition of a pulse cancellation circuit 28 between the output of the receiver 26 and pulse decoder 34. As illustrated the transponder comprises an omnidirectional antenna for instance, coupled through duplexer 24 to transmitter 36 and receiver 26 for receiving the pulse train emitted by the interrogator system above described. A two pulse decoder circuit 34 is coupled to the transmitter 36 for actuating the transmitter only upon receipt of a pair of time spaced pulses having the time spacing of pulses 21 and 22 of Figure 5.

In operation, decoder 34 which may be any of a number of conventional two pulse discriminator circuits such as shown in volume III, sections 9.8 and 9.9 of the MIT Radiation Laboratory Series, acts to energize transmitter 36 only when a pair of positive pulses having the time spacing of pulses 21 and 22 is impressed on the input to this circuit. Accordingly, to permit keying of transmitter 36 by the decoder 34 only when pulses 21 and 22 are received, the detected video output of the receiver 26 is applied through a pulse cancellation circuit 28 to the input of decoder 34. Circuit 28 includes a cancellation tube 30 which receives a positive pulse output of receiver 26 directly through line 35 and indirectly through delay line 25 and polarity inverter 27. Delay line 25 acts to delay the output of receiver 26 by an amount equal to t_0 , the time spacing between lockout pulse 20 and the first pulse 21 of the interrogator pulses 21 and 22. The signal applied to grid 31 of cancellation tube 30 must have a polarity opposite to the signal at grid 32 as will be explained later. As all signals at the output of receiver 26 received from transmitters 4 and 6 will have the same polarity, positive in this example, it is necessary to insert polarity reversing circuit 27 between delay line 25 and

cancellation stage 30. The output at the plate of tube 30 is in turn applied to a biased clipper amplifier 33 which translates only negative inputs thereto above a predetermined and preferably adjustable amplitude.

The respective inputs to cancellation tube 30 are combined in opposition (positive pulses on grid 32 and negative pulses on grid 31), so that, when pulses arrive simultaneously from line 35 and polarity inverter 27, no pulse will appear in the output circuit. Additionally, since clipper 33 will pass only negative pulses, only those pulses which are received directly on line 35 have the correct polarity to pass through the clipper 33. Thus, when the pulse train depicted in Figure 5 including pulses 20, 21 and 22 is received, the delayed pulse 20 cancels the undelayed pulse 21 whereby only the undelayed pulses 20 and 22 are passed by the clipper 33. But since these pulses do not have the proper time spacing for operation of decoder 34 no reply signal is transmitted. In the absence of pulse 20, however, no such cancellation of the first pulse 21 occurs. In this case, the pulse pair 21 and 22 are free to pass through the system and actuate decoder 34 which in turn triggers transponder transmitter 36 to initiate a reply signal.

The clipper 33 in addition to rejecting pulses of the wrong polarity can by adjustment of its clipping threshold, eliminate signals below a given level from the output of the cancellation tube 30. In the event of only partial cancellation of pulse 21 by pulse 20, a small pulse could result that might be of sufficient magnitude to actuate decoder 34. By means of this pulse clipper, these signals are eliminated, thereby resulting in more positive sharpening action. Inasmuch as the clipping action may be made adjustable, a means is provided for controlling the amount of azimuth sharpening that is brought about by the overall system.

Returning to the interrogator of Figure 1, the signal radiated by transponder antenna 23 is picked up by antenna element 12 of antenna 8. The reason for antenna elements 12 being used for this purpose, of course, is that maximum sensitivity can be realized due to the beam characteristics of these elements. Connected to antenna 8 through duplexer 16 is responder receiver 18 and indicator unit 19 on which the reply signals from transponder transmitter 36 are displayed. Indicator unit 19 may be the PPI of the associated radar set (such as shown in the Stokes patent, supra) or any other suitable presentation system. Signals picked up by antenna element 12 will be detected by receiver 18 and displayed on indicator unit 19.

Figure 3 presents an embodiment of another interrogator-responder unit suitable for use with this invention. This unit differs from that shown in Figure 1 in that only a single transmitter 40 is required. A high power R. F. switch 42 is connected between the transmitter 40 and antenna elements 10, 12, and 14. As interrogator modulator 48 keys transmitter 40, the R. F. switch 42 shifts the output of this transmitter 40 from one beam pattern to the other in a time sequence such that lockout pulses are radiated from antenna elements 10 and 14 and coded pulses are radiated from antenna elements 12. Interrogator modulator 48 may be used to actuate the switching mechanism 42 so as to accomplish the above described action. The R. F. switch 42 may be of the type shown in Patent No. 2,592,551 granted to Warren H. Flarity. The output at terminal A of interrogator pulse modulator 48 may be used to switch the output of R. F. switch 42 to antenna elements 10 and 14 through switching line 46. When signal generator 40 is keyed by the output of this terminal, the R. F. switch is simultaneously actuated.

Although the embodiments disclosed in the preceding specification are preferred, other modifications will be apparent to those skilled in the art which do not depart from the scope of the broadest aspects of the present invention.

The invention described herein may be manufactured and used by or for the Government of the United States

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of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. An electronic identification system comprising an interrogator system which comprises first and second signal generator means, pulse modulator means operative to pulse modulate said first signal generator means with recurring lockout pulses and to pulse-modulate said second signal generator means with recurring coded pulses having a given time-relation to said lockout pulses, directional antenna means having first and second antenna elements, said first antenna element having a radiation pattern with a sharp null, said second antenna element having a radiation pattern with a maximum in the direction of said null, said first antenna element being energized by said first signal generator means and said second antenna element being energized by said second signal generator means, a transponder system including a remote receiver means operative to receive the signal emitted by said directional antenna means, pulse discriminator means responsive to the output of said remote receiver means producing an output according to said coded pulses only when the received lockout pulses are less than a given amplitude, third signal generator means responsive to the output of said discriminator means, omni-directional antenna means energized by said third signal generator means, an interrogator receiver means receiving the signal emitted by said omni-directional antenna means, and presentation means responsive to said interrogator receiver means.

2. An electronic identification system comprising an interrogator system including first signal generator means, pulse modulator means modulating said first signal generator means with recurring lockout pulses and with recurring coded pulses bearing a fixed time relation to said lockout pulses, directional antenna means having first and second antenna elements, said first antenna element having a radiation pattern with a sharp null, said second antenna element having a radiation pattern with a maxima in said null, switching means connecting the output of said signal generator to said first antenna element only when said signal generator is modulated by lockout pulses and to said second antenna element only when said signal generator is modulated by coded pulses, a transponder system having first receiver means receiving the signal emitted by said directional antenna means, pulse discriminator means responsive to the output of said first receiver means producing an output according to said coded pulses only when the received lockout pulses are less than a given amplitude, second signal generator means responsive to the output of said pulse discriminator means, omni-directional antenna means energized by said second signal generator means, an interrogator receiver means receiving the signal emitted by said omni-directional antenna means, and presentation means responsive to said second receiver means.

3. An identification system comprising radio frequency transmitting means, means operative to modulate said radio frequency transmitting means with recurring lockout pulses and additionally with recurring coded pulse signals, the lockout pulses having a fixed time relation to said recurring coded pulses, directional antenna means operative to radiate said lockout pulses according to a first radiation pattern having a sharp null in a given direction, and radiating said coded pulses according to a second antenna pattern having maximum radiation in the direction of said null, remote transponder means transmitting a radio frequency signal responsive to the coded pulses as received by said transponder means when said lockout signals as received by said transponder means falls below a given level, receiving means at said transmitting means detecting signals emitted by said transponder means.

4. An identification system comprising first and second radio frequency transmitting means, pulse modulator

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means operative to modulate said second radio frequency transmitting means with coded pulses a given time interval after actuating said first radio frequency transmitting means with a lockout pulse, a remote transponder means operative to transmit a radio frequency signal responsive to said second radio frequency transmitting means when the lockout signal received from said first transmitting means falls below a given level, and receiving means at said first and second transmitter means operative to detect signals emanated by said transponder means.

5. An electronic identification system comprising a transponder means operative to emanate a radio frequency signal in response to the receipt of coded pulses of predetermined spacing when said coded pulses are not accompanied by lockout pulses of given time spacing from said coded pulses, interrogator means transmitting recurrent coded pulse signals and lockout pulse signals of a given time relation, said lockout pulse signals being transmitted in a radiation pattern with a sharp null and said coded pulse signals being transmitted in a radiation pattern with a maxima in the direction of said sharp null, and responder means responsive to the signal emanated by said transponder means to indicate the presence of said transponder.

6. An electronic identification system comprising an interrogator system having a pulse modulating means operative to produce recurrent control pulses in time relation to recurrent coded pulses, said pulses operable to actuate a signal generator means, switching means operative to selectively direct the output of said signal generator means to a first antenna means when said signal generator is actuated by said coded pulses and to second antenna means when said signal generator is actuated by said control pulses, said first antenna means having a lobe with maximum radiation in a given direction, said second antenna means having two lobes with a sharp null in said given direction, a remote receiver means receiving said pulsed signal, pulse discriminator means producing an output signal in accordance with said coded pulses only when said control pulse is not received by said first receiver means, radio frequency transmitter means responsive to the output of said pulse discriminator means, and responder receiving means at the interrogator actuating an indicator upon reception of a signal from said radio frequency transmitter means.

7. An electronic identification system comprising transponder means responsive to coded pulses of predetermined spacing operative to transmit a radio signal to a responder receiver when said coded pulses are not accompanied by a lockout pulse, interrogator means transmitting said coded pulses and said lockout pulses in spaced-time relation, said lockout pulse being transmitted according to a radiation pattern with a sharp null in a given direction and said coded pulses being transmitted according to a radiation pattern beamed in the direction of said sharp null.

8. In an electronic identification system comprising an interrogator means, and transponder means operative in response to coded signals from said interrogator means to transmit identifying signals to a responder receiver; first means operative to transmit coded signals according to a radiation pattern having maximum radiation in a given direction, second means at the same location as said first means operative to transmit disabling signals according to a radiation pattern having a null in said given direction, means operative to allow said transponder to respond to said coded signals only when signals received from said second means are less than a given signal strength, and to prevent said transponder from responding to said coded signals when signals received from said second means are greater than a given signal strength.

9. In an electronic identification system comprising an interrogator means and transponder means operative in response to groups of pulse signals coded by time-separation from said interrogator means to transmit identi-

5 fying signals to a responsor receiver; means operative to transmit a disabling pulse signal from said interrogator along with each group of said coded pulse signals, said disabling pulse signals being transmitted according to a radiation pattern having a null in a given direction, and means operative to prevent response by said transponder means to a given group of coded pulse signals when the disabling signal associated with said given group is greater than a given signal strength.

10 10. In an electronic identification system including an interrogator-responsor and a transponder; transmitter means in said interrogator-responsor adapted to transmit narrow beam interrogating pulse signals and wide beam disabling pulse signals, said disabling pulse signals having a null in the azimuthal position of said narrow pulse 15

signals; and means to vary the effective null width of said disabling pulse signals.

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