(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 982 800 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.03.2000 Bulletin 2000/09

(51) Int Cl.^{7}: **H01Q 15/00**

(21) Application number: **99306458.3**

(22) Date of filing: **17.08.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **27.08.1998 US 140870**

(71) Applicant: **LUCENT TECHNOLOGIES INC.**
Murray Hill, New Jersey 07974-0636 (US)

(72) Inventors:
- **Kaminski, Joseph Walter**
  Long Valley, New Jersey 07853 (US)
- **Kolsrud, Arild**
  Bridgewater, New Jersey 08807 (US)

(74) Representative:
Johnston, Kenneth Graham et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green Essex, IG8 OTU (GB)

(54) **High frequency delay device using frequency selective surfaces**

(57) A broadband frequency selective delay device is provided in a small configuration. A source antenna (34) transmits the multifrequency signal in the direction of several frequency selective surfaces (38, 40, 42). Each of the frequency selective surfaces (38, 40, 42) redirects a different frequency component of the signal to a receive antenna (46) that combines the redirected signal components to produce a compressed signal or a stretched signal, depending on the way in which the frequency selective devices are arranged.

EP 0 982 800 A2

Description

Cross Reference To Related Invention

[0001] This application is related to the following commonly assigned US Patent Application: "Filter Including A Microstrip Antenna And A Frequency Selective Surface," filed July 15, 199, Serial Number. 09/115690.

Field of the Invention

[0002] The present invention relates to signal delay devices; more particularly, frequency selective delay devices.

Description of the Related Art

[0003] In many applications such as radar and communication system applications, multifrequency signals such as frequency coded signals are transmitted. An example of a multifrequency signal is illustrated in FIG. 1. FIG. 1 illustrates upchirp FM pulse 10 in which the frequency increases with time. The figure illustrates pulse 10 propagating in the direction of arrow 12. The multifrequency pulse in this example has three major frequency components. Section 14 contains a low frequency signal component, section 16 contains a mid-range frequency signal component and section 18 contains a higher frequency signal component. Frequency selective delay devices have been used in the past to compress or stretch multifrequency pulses. For example, in a pulse compression application the frequency selective delay devices compress the pulse by providing little or no delay to high frequency components 18, providing some delay to mid-frequency range components 16, and providing a larger amount of delay to lower frequency components 14.

[0004] In the past, devices such as a magnetostatic delay devices were used. The magnetostatic delay line worked well with high frequency signals, such as 4 Gigahertz signals; however, it was a heavy, bulky and expensive device. SAW devices (surface acoustic wave) have been used and are less bulky than the magnetostatic delay lines; however, SAW devices do not work well above 1 Gigahertz.

[0005] As a result, there is a need for a frequency selective delay device that is small and works well over a broad range of frequencies including microwave and millimeter wave frequencies.

Summary of the Invention

[0006] The present invention solves the aforementioned problem by providing a broadband frequency selective delay device in a small configuration. A source antenna transmits the multifrequency signal in the direction of several frequency selective surfaces. Each of the frequency selective surfaces redirects a different frequency component of the signal to a receive antenna that combines the redirected signal components to produce a compressed signal or a stretched signal, depending on the way in which the frequency selective devices are arranged.

[0007] In one embodiment, a signal such as an upchirp pulse is compressed. An upchirp pulse is a signal where lower frequency components are transmitted before higher frequency components. In this embodiment, the first frequency selective surface redirects the higher frequency components of the signal and allows the other components to pass. Subsequent frequency selective surfaces redirect components of the multifrequency signal while allowing the lower frequency components to pass until the lowest frequency signal has been redirected. This results in the different frequency components of the multifrequency signal being redirected by different frequency selective devices. The different frequency selective devices are positioned at different distances from the receive antenna. These different distances result in each of the different frequency components of the multifrequency signal traveling different distances. In this embodiment, the signal is compressed because the lower frequency signal component travels the longest distance and the higher frequency components travel shorter distances.

[0008] In another embodiment, an upchirp pulse is stretched by reversing the order in which the frequency selective surfaces are arranged. In this embodiment the first frequency selective device redirects lower frequency components and subsequent frequency selective devices redirect higher frequency components. This results in the signal being stretched because lower frequency components travel a shorter distance than the higher frequency components.

[0009] In yet another embodiment, a small device package is provided by using a material with a high dielectric constant inside the frequency selective delay device which will increase the total time delay and further increase the delay ratio between the different frequency components.

Brief Description of the Drawings

[0010]

FIG. 1 illustrates a multifrequency signal;
FIG. 2 illustrates a delay device using frequency selective surfaces;
FIG. 3 illustrates a frequency selective surface;
FIG. 4 illustrates a graduated frequency selective surface; and
FIG. 5 illustrates a high frequency delay device using graduated frequency selective surfaces.

Detailed Description of the Invention

[0011] FIG. 2 illustrates a high frequency delay device using frequency selective surfaces. The delay device is enclosed in enclosure 30 which should be fabricated from a conductive material such as aluminum in order to prevent radiation leakage. Input 32 provides the received signal to antenna 34. Antenna 34 may be implemented using a patch, spiral log periodic or broadband antenna. Antenna 34 transmits, for example, the upchirp FM signal of FIG. 1 in the direction of arrow 36 toward frequency selective surfaces 38, 40 and 42. Frequency selective surface 38 reflects or redirects high frequency signals and allows lower frequency signals to pass. For example, frequency selective surface 38 reflects signals corresponding to component 18 of pulse 10 while allowing signal components 16 and 14 to pass. In a similar fashion frequency selective surface 40 reflects signal component 16 while allowing signal component 14 to pass. Frequency selective surface 42 will then reflect signal component 14. The distances traveled by each of the signal components is controlled by varying angle 44 and/or the distances between the frequency selective surfaces. Further delay between the different frequency components can be introduced by filling the media with high dielectric constant material which decreases the propagation velocity and thereby increases the relative delays between the frequency components. For example, the distance L1 traveled by the higher frequency component 18 can be adjusted relative to the longer distance L2 traveled by lower mid-range frequency component 16 by varying the distance between frequency selection surfaces 38 and 40. Likewise, the relative distance traveled by lowest frequency component 14 can be adjusted by varying the distance between frequency selective surface 42 and frequency selective surfaces 38 and 40. Since distance L1 is less than L2 which is less than L3, frequency components 14 and 16 will be delayed relative to component 18, and component 14 will be further delayed relative to component 16. This effectively compresses the multifrequency signal. The signals reflected by the frequency selective surfaces are received by antenna 46 and provided to output line 48. Antenna 46 may be implemented as a patch or spiral antenna.

[0012] In another embodiment, an upchirp pulse is stretched by reversing the order in which the frequency selective surfaces are arranged. In this embodiment the first frequency selective device redirects lower frequency components and subsequent frequency selective devices redirect higher frequency components. This results in the lower frequency components traveling a shorter distance than the higher frequency components and thereby stretches the signal.

[0013] It should also be noted that, for example, multifrequency signals such as downchirp FM pulses may be stretched or compressed. (In a downchirp pulse, high frequency signal components are transmitted before lower frequency components.) When stretching the pulse, the input signal is transmitted towards frequency selective surfaces arranged such that the higher frequency components travel a shorter distance than the lower frequency components. When compressing the downchirp pulse, the frequency selective devices are arranged such that the lower frequency components travel a shorter distance than the higher frequency components.

[0014] The overall size of the frequency selective delay device may be decreased by filling the volume enclosed by enclosure 30 with a material having a high dielectric constant such as ceramics with relative dielectric constant (ε_r) ranging from 10 to over 10,000.

[0015] FIG. 3 illustrates a frequency selective surface. The frequency selective surface comprises metal film patterns 60 that are located on substrate 62. Metal film patterns 60 may be constructed using a conductive material such aluminum, copper, silver or tin, and substrate 62 may be constructed using fiberglass or KEVLAR type polyamide material sheets that are, for example, between 1 and 5 mils thick. (KEVLAR is a registered trademark of E. I. DuPont.) Patterns 60 are illustrated as squares but it is also possible to have patterns such as patterns 64 on substrate 68 or circular patterns 70 on substrate 72. The frequency selectivity of the surfaces are based on the dimensions and shapes of these patterns. The exact dimensions of these circuits can be designed using well-known techniques discussed in publications such as "Double-Square Frequency Selective Surfaces and Their Equivalent Circuit," by R. J. Langley and E. A. Parker, Electronics Letters, pages 675-677, Vol. 19, No. 17, August 18, 1983; "Equivalent-Circuit Models for Frequency-Selective Surfaces at Oblique Angles of Incidence," by C. K. Lee and R. J. Langley, IEEE Proceeding, pages 395-399, Vol. 132, Pt. H, No. 6, October 1985; and "On the Theory of Self-Resonant Grids," by I. Anderson, The Bell System Technical Journal, pages 1725-1731, Vol. 54, No. 10, December 1975.

[0016] FIG. 4 illustrates an example of a frequency selective delay device using graduated frequency selective surfaces. The FM upchirp is provided on input line 100 to antenna 102. Antenna 102 may be an antenna such as a patch, spiral log periodic or broadband antenna. The signal is transmitted in the direction of arrow 104 towards graduated frequency selective surface 106. Graduated frequency selective surface 106 has different reflective properties depending on the position or area along the surface. Section 108 of frequency selective surface 106 reflects low frequency signals such as component 14 of signal 10, but allows signals associated with higher frequencies to pass through to absorptive material 110. Section 112 of frequency selective surface 106 reflects frequency components such as frequency component 16 of signal 10 and allows other frequencies to pass into absorptive material 110. Section 114 of frequency selective surface 106 reflects high frequency signals such as signal components 18 of signal 10 and allows other signals to pass to absorptive material 110. The signals reflected by frequency selective surface 106 are reflected in the direction of frequency selective surface 116. Frequency selective surface 116 operates in a fashion similar to frequency selective surface 106. That is, section 118 of frequency selective surface 116 reflects lower frequency signals such as component 14 of signal 10, but allows the higher and mid-range frequency signals associated with components 16 and 18 to pass into absorptive material 120. Section 122 of frequency selective surface 116 reflects frequency component 16 of signal 10 but allows the other frequency components to pass through to absorptive material 120. Section 124 of frequency selective surface 116 reflects high frequency components such as components 18 of signal 10 while allowing the other components to pass through to absorptive material 120. The signals reflected by frequency selective surface 116 are reflected in the direction of received output antenna 126 which combines the reflected signals and provides an output signal on output 128. As a result of this arrangement, higher frequency signals travel a shorter path illustrated by the sum of lines 130, 132 and 134, while lower frequency signals travel a longer path illustrated by the sum of lines 136, 138 and 140. This results in the higher frequency signals traveling a shorter distance than the lower frequency signals. The shorter propagation path traveled by the higher frequency signals essentially compresses the multifrequency pulse that was provided at input 100.

[0017] As was discussed with regard to FIG. 2, signals can be compressed or stretched by adjusting the distances traveled by different frequency components. These distances may be adjusted by changing the order of the sections on the graduated frequency selective surfaces.

[0018] FIG. 5 illustrates a graduated frequency selective surface 160 that may be used in the delay device of FIG. 4. As discussed with regard to FIG. 3, the frequency selective surface 160 comprises conductive materials 162 arranged on substrate 164. Conductive materials 162 may be constructed out of tin, copper, silver or aluminum while substrate 164 may be fabricated from materials such as fiberglass or KEVLAR type polyamide material sheets that are between, for example, 1 and 5 mils thick. Portion 166 of the graduated frequency selective surface 160 has a metal pattern that resonates or reflects low frequency signals such as signal component 14 of signal 10, but allows mid-range frequency and higher frequency signals to pass through. Section 168 of frequency selective surface 160 contains a metal pattern that is reflective to mid-range frequency signals such as signal component 16 of signal 10, but allows the other frequency components to pass. Section 170 of frequency selective surface 160 contains patterns that are reflective to high frequency signals such as component 18 of signal 10, but allows the lower frequency components to pass through.

Claims

1. A frequency sensitive signal delay device, characterized by:

a source antenna (34) that transmits a signal having a plurality of signal components with different frequencies;
a plurality of frequency selective surfaces (38, 40, 42) positioned to redirect the signal, each frequency selective surface redirecting a signal component within a different range of signal frequencies to create a plurality of redirected signals; and
a receive antenna (46) positioned to receive the redirected signals.

2. The frequency sensitive signal delay device of claim 1, characterized in that the source antenna (34) is a patch antenna.

3. The frequency sensitive signal delay device of claim 1, characterized in that the receive antenna is a patch antenna.

4. A frequency sensitive signal delay device, characterized by:

a source antenna (102) that transmits a signal having a plurality of signal components with different frequencies;
a first graduated frequency selected surface (106) positioned to redirect the signal, the first graduated frequency selected surface having a plurality of different areas, each area redirecting signal components within different ranges of signal frequencies to create a first plurality of redirected signals;
a second graduated frequency selected surface (116) positioned to redirect at least some of the first plurality of redirected signals, the second graduated frequency selected surface having a plurality of different areas, each area redirecting signals within different ranges of signal frequencies to create a second plurality of redirected signals; and
a receive antenna (126) positioned to receive the second plurality of redirected signals.

5. The frequency sensitive signal delay device of claim 4, characterized in that the source antenna is a patch antenna.

6. The frequency sensitive signal delay device of claim 4, characterized in that the receive antenna is a patch antenna.

FIG. 1

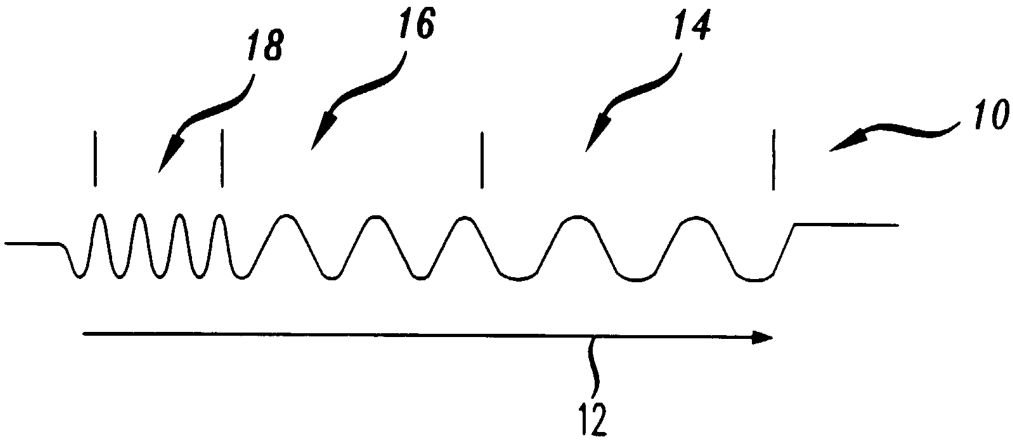


FIG. 2

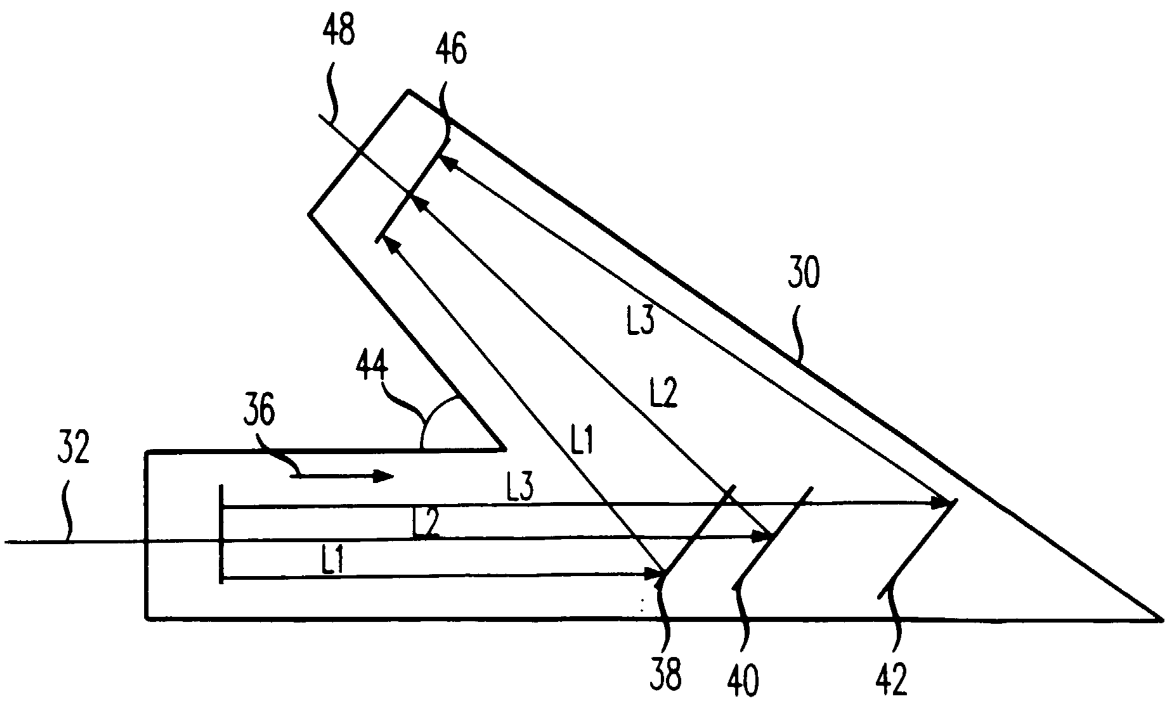


FIG. 3

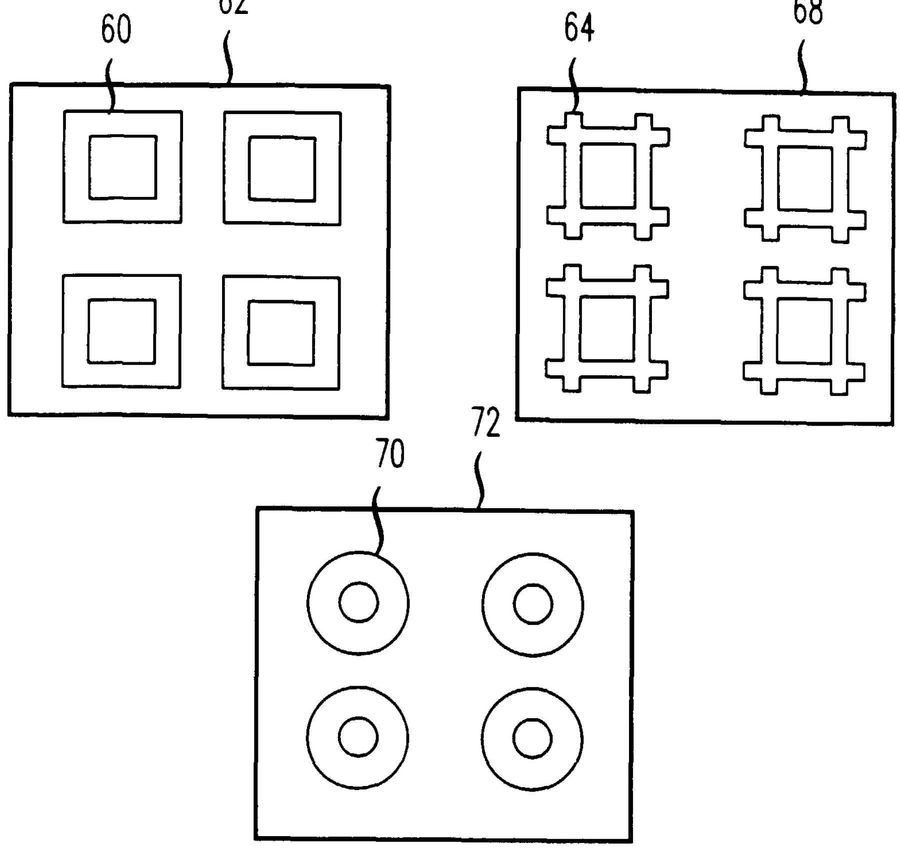
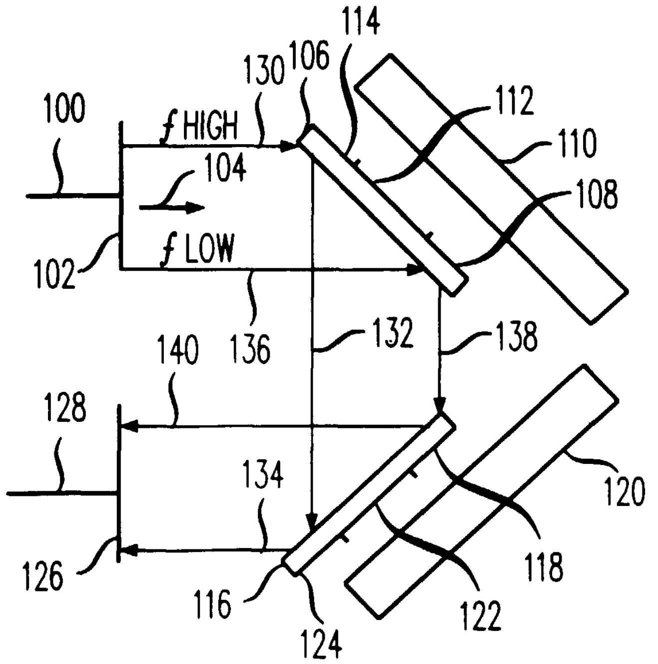

60
62
64
68
70
72

FIG. 4


100
102
104
106
108
110
112
114
116
118
120
122
124
126
128
130
132
134
136
138
140
f HIGH
f LOW

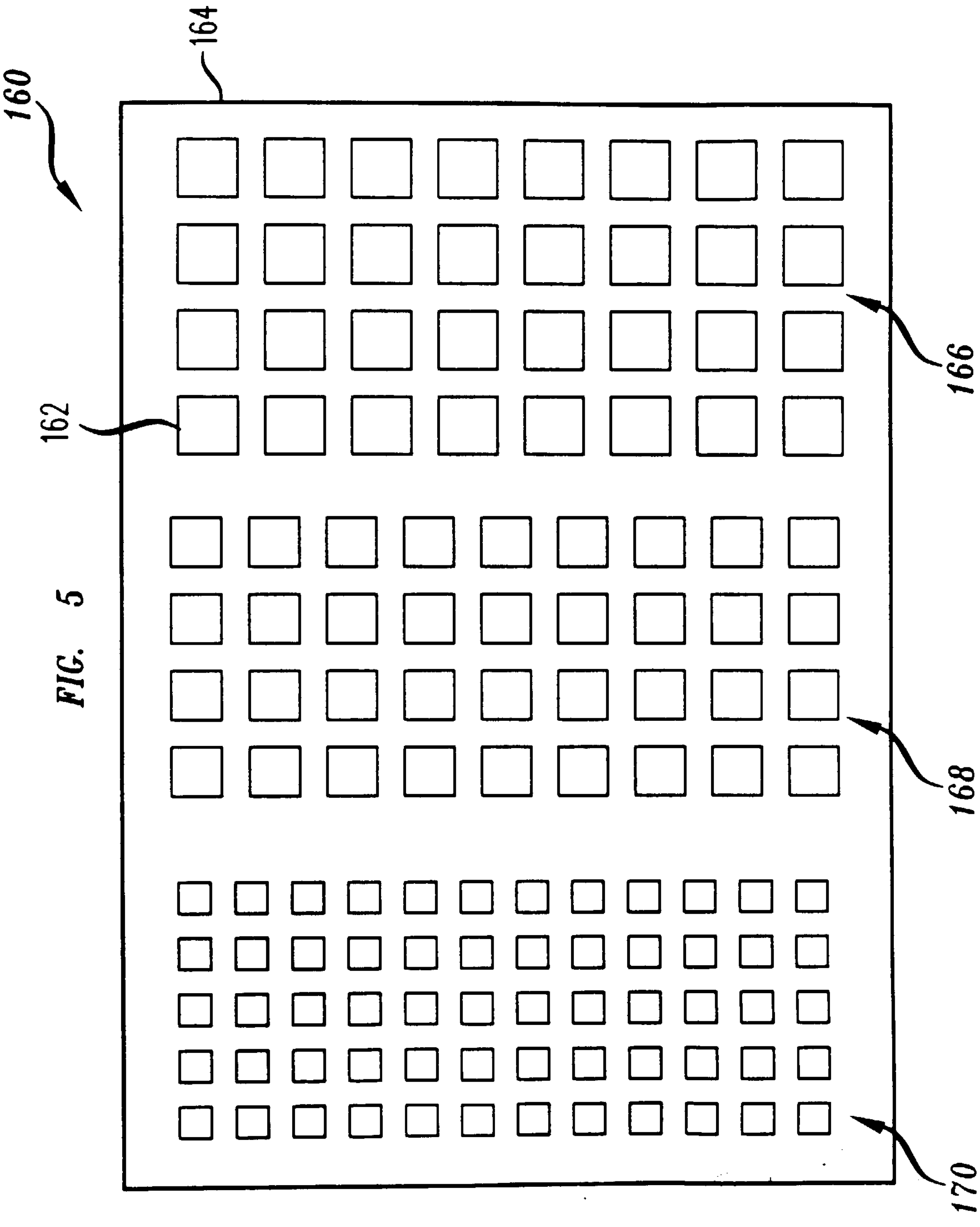


FIG. 5