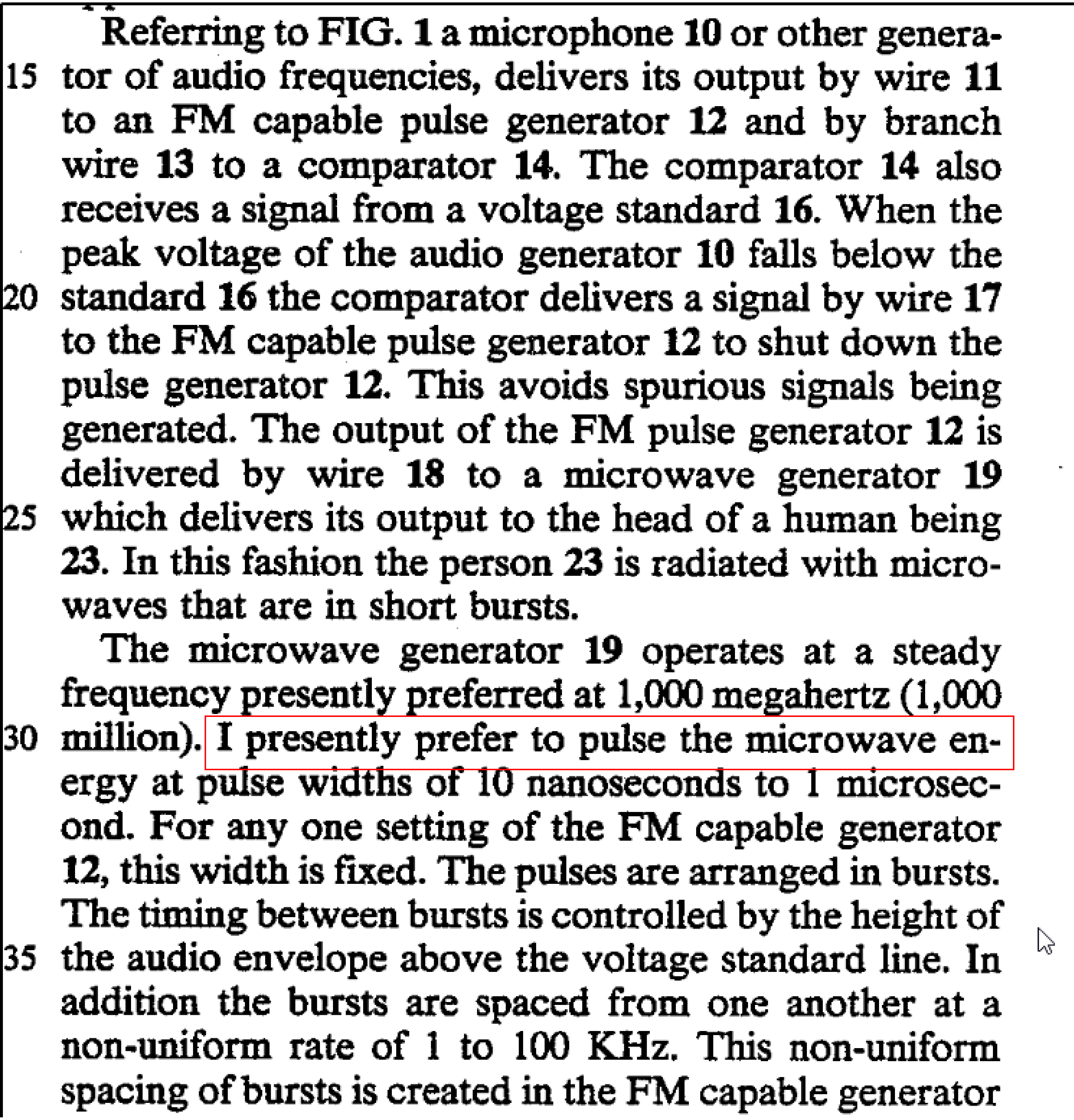

TechDemoSat-1



Referring to FIG. 1 a microphone **10** or other generator of audio frequencies, delivers its output by wire **11** to an FM capable pulse generator **12** and by branch wire **13** to a comparator **14**. The comparator **14** also receives a signal from a voltage standard **16**. When the peak voltage of the audio generator **10** falls below the standard **16** the comparator delivers a signal by wire **17** to the FM capable pulse generator **12** to shut down the pulse generator **12**. This avoids spurious signals being generated. The output of the FM pulse generator **12** is delivered by wire **18** to a microwave generator **19** which delivers its output to the head of a human being **23**. In this fashion the person **23** is radiated with microwaves that are in short bursts.

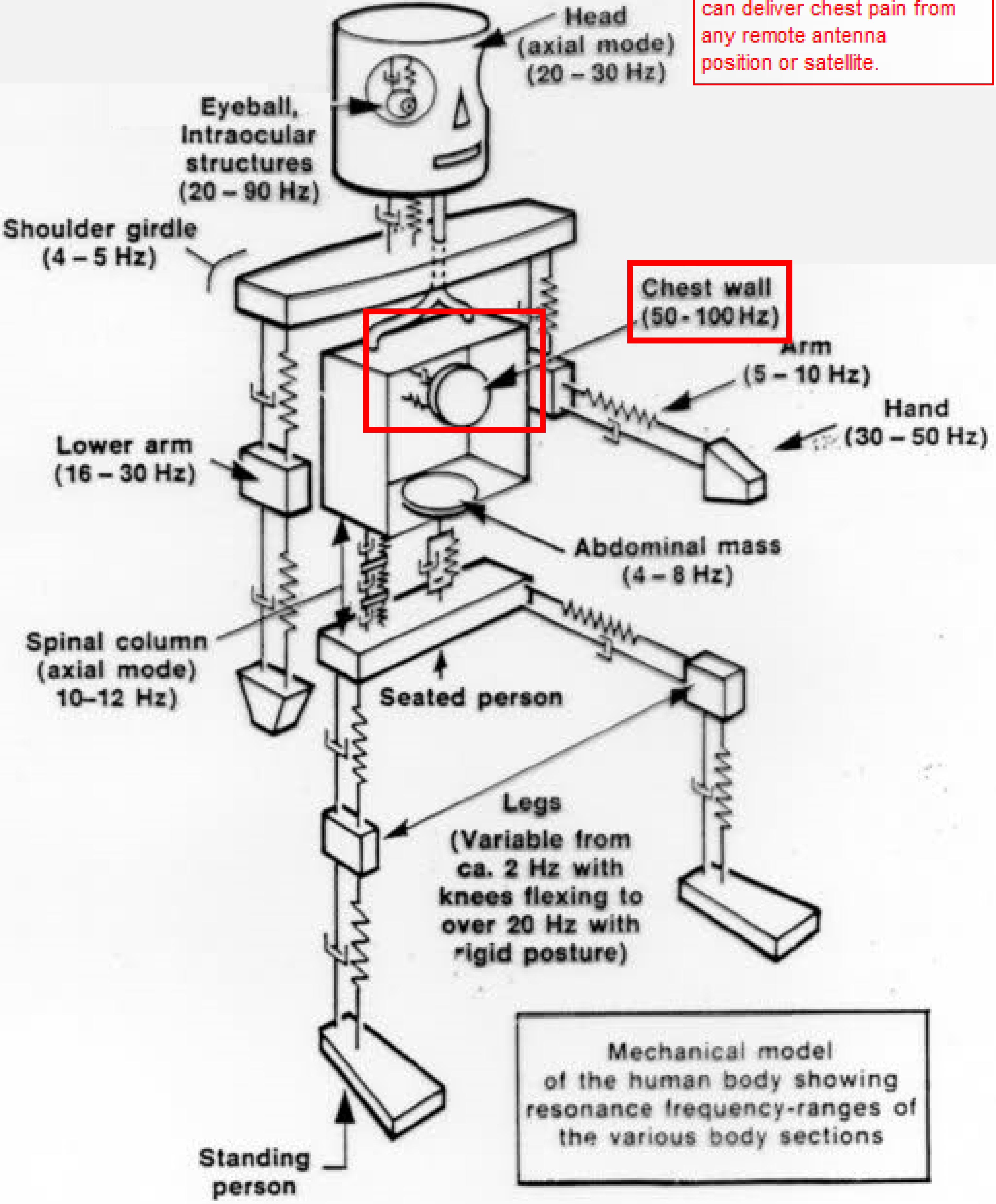
The microwave generator **19** operates at a steady frequency presently preferred at 1,000 megahertz (1,000 million). I presently prefer to pulse the microwave energy at pulse widths of 10 nanoseconds to 1 microsecond. For any one setting of the FM capable generator **12**, this width is fixed. The pulses are arranged in bursts. The timing between bursts is controlled by the height of the audio envelope above the voltage standard line. In addition the bursts are spaced from one another at a non-uniform rate of 1 to 100 KHz. This non-uniform spacing of bursts is created in the FM capable generator

TOP SECRET

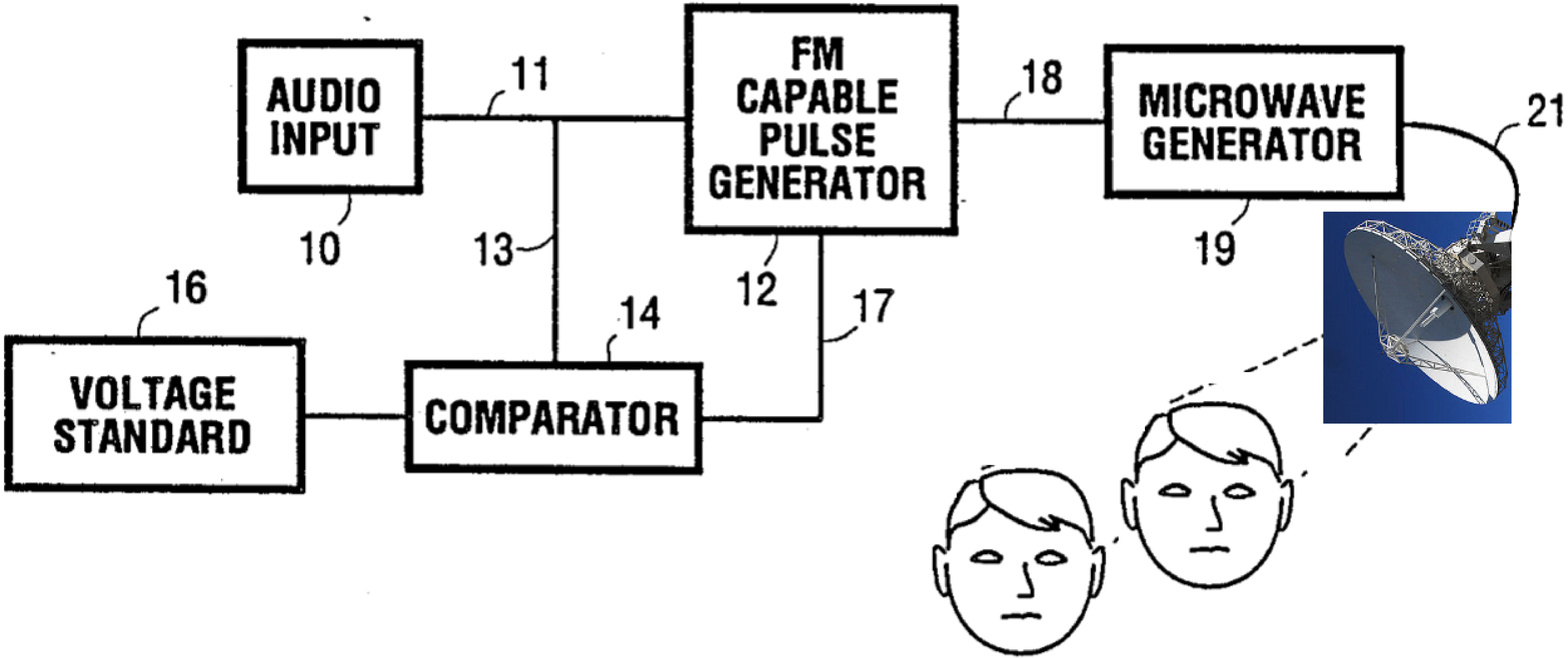
THE HUMAN BODY RESONANCE FREQUENCIES. MECHANICAL MODEL.

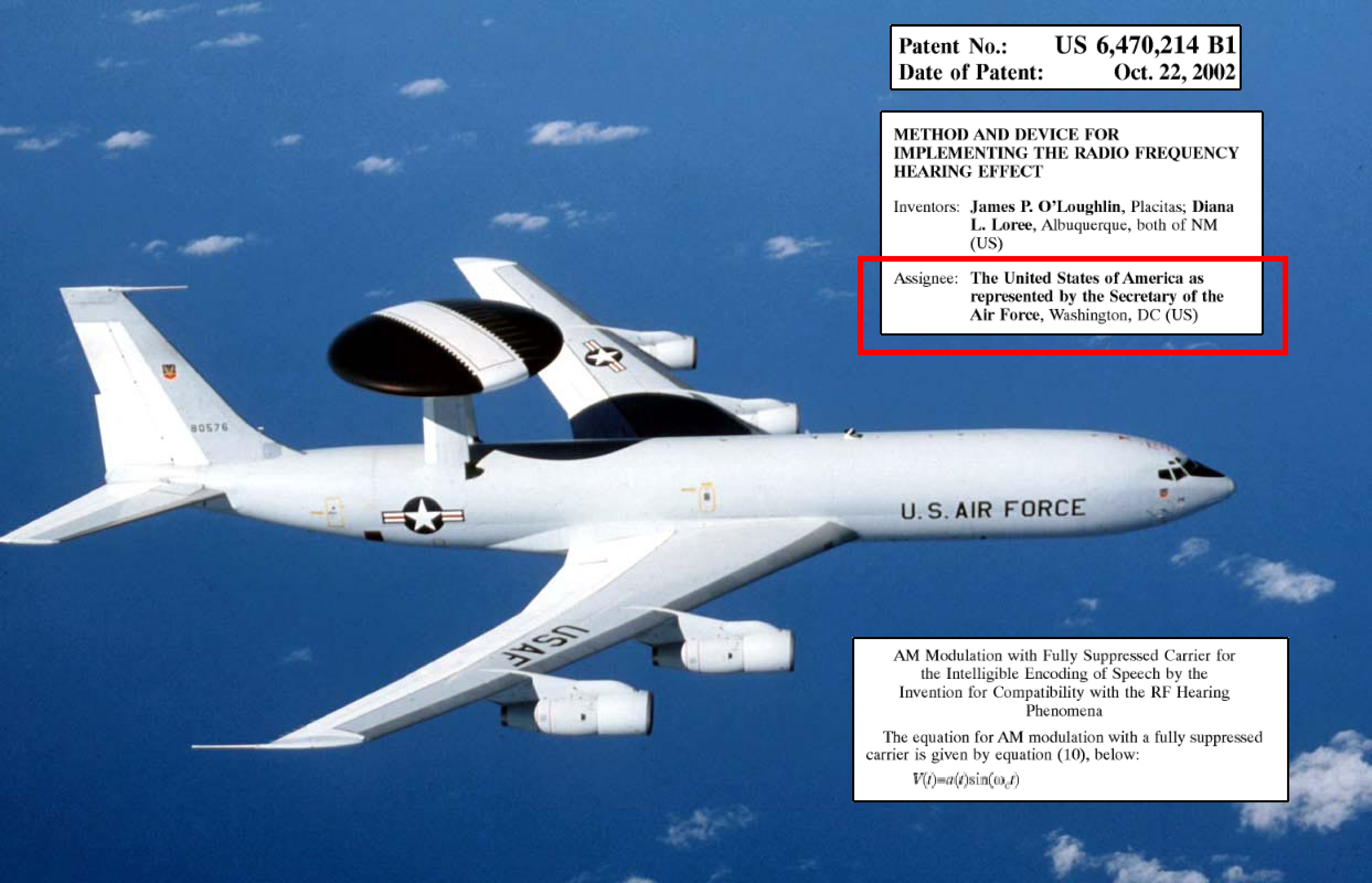
Simple graphic to show of how to produce eyepain, less awareness or vision on a remote target.

A combination of frequencies can deliver chest pain from any remote antenna position or satellite.



Mechanical model of the human body showing resonance frequency-ranges of the various body sections


AUDIO INPUT
10
11
13
FM CAPABLE PULSE GENERATOR
12
18
MICROWAVE GENERATOR
19
21
16
VOLTAGE STANDARD
14
COMPARATOR
17



Patent No.: US 6,470,214 B1
Date of Patent: Oct. 22, 2002

METHOD AND DEVICE FOR IMPLEMENTING THE RADIO FREQUENCY HEARING EFFECT

Inventors: **James P. O'Loughlin**, Placitas; **Diana L. Loree**, Albuquerque, both of NM (US)

Assignee: **The United States of America as represented by the Secretary of the Air Force**, Washington, DC (US)

AM Modulation with Fully Suppressed Carrier for the Intelligible Encoding of Speech by the Invention for Compatibility with the RF Hearing Phenomena

The equation for AM modulation with a fully suppressed carrier is given by equation (10), below:

$$V(t)=a(t)\sin(\omega_c t)$$

WE HIJACK AMERICAN AND RUSSIAN SPYSATELLITES WITH MAGNETRON SHOOTERS - BECAUSE WE ARE TIRED OF HEARING IN OUR HEADS THAT "WE ARE NOT GOD" - 50 TIMES PER DAY.

/ The people of Scandinavia.

Regeringskansliet

Regeringskansliet
103 33 Stockholm
Växel 08-405 10 00

FÖRSÄTTSBLAD ANGÅENDE DE MEST INTRESSANTA AMERIKANSKA PATENTEN I DENNA REGERINGS MAPP ELLER PÄRM

MULTIFUNCTIONAL RADIO FREQUENCY DIRECTED ENERGY SYSTEM-

On the other hand, an RADIO FREQUENCY DIRECTED ENERGY weapon system can go after a
broad range of targets (electronics, biological, ordinance, structures, etc.)
due to its relatively large radiated power.
A prior knowledge of the intended target characteristics is
typically not required because the RADIO FREQUENCY DIRECTED ENERGY weapon either burns-out
or overwhelms its target by the shear amount of power it radiates.

AMERICAN PATENT US 7,629,918 B2.
MULTIFUNCTIONAL RADIO FREQUENCY DIRECTED ENERGY SYSTEM-

APPARATUS FOR AUDIBLY COMMUNICATING SPEECH USING THE
RADIO FREQUENCY HEARING EFFECT.
AMERICAN PATENT US 6,587,729 B2.

== Note! In the following patent they speak about "intelligeble signals" or "intelligeble speech",
== which in these American (U.S.A.) Patent texts, within this Government document of 56 pages plus photos,
== means exactly the same as "brain understandable microwave speech without the normal air soundwaves to the ear".
== A totally opposite comparison, would roughly be, a bad noisy radio transmission of any human voice that speaks.
== In one Patent the Americanos say that there is certainly possible to transmit tones, but not as complex as
== the human speech, to the the brains of a group, via given in Patent, microwave signals.
== But, simply enough, there's another American Patent that takes care of "that problem" too.
== Plus, and in, THE PATENT US 6,587,729 B2, it all ends with, I.E. "it works".
== So when YOU ADD UP all the American Patents together, and look at their own Satellite Photos,
== a satellite photo that was taken from the Department of Defense, (DoD), and released onto the Internet, as the "First Spy Satellite Selfie",
== So, YES - the Americans (U.S.A.) - GOT the technology to mixture our brain waves, here at ground level,
== AND they have already built it ABOVE US ALL IN EUROPE up there in orbit. This document contains proof of that.
== It's called spy-satellites with Pulsed Magnetron Cannons. (Mental attack microwave guns, that is pulsed,
== and fires a blast of 20 uniformly made pulses, within a few milliseconds of time.
== Then the brain (or brains) tries to handle, what it is thinking, are YOUR actual "thought process", for you.
== And this technology was initially developed and later built by the U.S.A., according to their wishes, to cause,
== "Behavioral Changes In Foreign Governments", like that of Vietnam. You must read the full Patents, Sir or Lady.
== I have researched this technology for years. And here's my provable findings. // Gustav Norström. End of Note!

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

BACKGROUND OF THE INVENTION

This invention relates to the modulating of Signals on carriers, which are transmitted and the Signals intelligibly recovered, and more particularly, to the modulation of Speech on a carrier and the intelligible recover of the Speech by means of the Radio Frequency Hearing Effect.
The Radio Frequency (“RF") Hearing Effect was first noticed during World War II as a subjective “click” produced by a pulsed radar Signal when the transmitted power is above a “threshold” level. Below the threshold level, the click cannot be heard.
The discovery of the Radio Frequency Hearing Effect, suggested that a pulsed RF carrier could be encoded with an amplitude modulated (“AM”) envelope. In one approach to pulsed carrier modulation, it was assumed that the "click” of the pulsed carrier was similar to a Data Sample and could be used to Synthesize both Simple and complex tones Such as Speech. Although pulsed carrier modulation can induce a Subjective Sensation for simple tones, it Severely distorts the complex Waveforms of Speech, as has been confirmed experimentally.
The presence of this kind of distortion has prevented the click proceSS for the encoding of intelligible Speech. An example is provided by AM Sampled data modulation
Upon demodulation the perceived speech Signal has Some

of the envelope characteristics of an audio signal. Consequently a message can be recognized as Speech when a listener is pre-advised that Speech has been sent. However, if the listener does not know the content of the message, the audio signal is unintelligible.
The attempt to use the click process to encode Speech has been based on the assumption that if simple tones can be encoded, speech can be encoded as well, but this is not So. A simple tone can contain Several distortions and Still be perceived as a tone whereas the Same degree of distortion applied to speech renders it unintelligible.

SUMMARY OF THE INVENTION

In accomplishing the foregoing and related object the invention uses a modulation process with a fully Suppressed carrier and pre-processor filtering of the input to produce an encoded output. Where amplitude modulation (AM) is employed and the pre-processor filtering is of audio speech input, intelligible Subjective Sound is produced when the encoded signal is demodulated by means of the RF Hearing Effect.

Suitable forms of carrier Suppressed modulation include Single Sideband (SSB) and carrier Suppressed amplitude modulation (CSAM), with both sidebands present.
The invention further provides for analysis of the RF hearing phenomena based on an RF to acoustic transducer model.

Analysis of the model suggests a new modulation process which permits the Radio Frequency Hearing Effect to be used following the transmission of encoded speech.

APPARATUS FOR AUDIBLY COMMUNICATING SPEECH USING THE
RADIO FREQUENCY HEARING EFFECT.
AMERICAN PATENT US 6,587,729 B2.

== Note! The "further provides for analysis of the RF hearing phenomena based on an RF to acoustic transducer",
== means that there are ground stations capable of analysing the overall microwave effects over an area.
== One ground station, or Listening Post (LP), used for "analysis", could actually be the "in law" protected American Embassy.
== Which we don't have access to. At least some Sat MW signals are focused to end up there at Hammarskölds Väg.
== End Note!

NOTERING: Man måste läsa igenom HELA patenttexten för att förstå vad man inte vill skriva på förstasidan.
I ett Patent har man enligt Patentet provkört, med gott resultat i laboratorium,
en stadig uteffekt av 40 KiloWatt.
Vilket i pulsat tillstånd kan ge en flera tusen gånger starkare uteffekt av mikrovågor,
och som då kan ge upphov till så kallade "mentala energifält", över en hel region,
stor som Skandinavien, om det skjuts från satellitavstånd.

Ett PATENT sökes därför att man
A/ har ensamrätt till uppfinningen och bestämmanderätt över vilka som ska kunna nyttja den framöver
B/ därför att ingen annan ska kunna producera eller sälja samma uppfinning på ett lagligt sätt

OVANPÅ DETTA ARK, HÄR TILL HÖGER,
SKA DET FINNAS ETT NASA,
(U.S.A. NATIONAL AIR AND SPACE ADMINISTRATION),
RUNT KLISTERMÄRKE, I FÄRGERNA VITT, BLÅTT OCH RÖTT.
DETTA SKA INTE VARA KOPIERAT I MASKIN, UTAN VARA PÅKLISTRAT,
OVANPÅ DETTA DKOUMENT, SOM ETT ORIGINAL, ÄKTHETSINTYG,
FRÅN DOKUMENTPRODUCENTEN GUSTAV NORSTRÖM 740621-1750.
SAMMA DEKAL SKA OCKSÅ FINNAS PÅ
BAKSIDAN AV DOKUMENTETS OMSLAGSSIDA, EN AMERIKANSK SPIONSATELLIT,
MOT SVART BAKGRUND OCH JORDKLOT.
DENNA NÄMNDA OMSLAGSBILD ÄR TAGEN FRÅN DEPARTMENT OF DEFENSE, U.S.A.
(DoD) ÅR 2017 AV G.N. (-Databasproffs).
-SLUT PÅ FÖRSÄTTSBLAD 2/2.

United States Patent [19]
Brunkan

[11] **Patent Number:** **4,877,027**
[45] **Date of Patent:** **Oct. 31, 1989**

[54] **HEARING SYSTEM**

[76] Inventor: **Wayne B. Brunkan,** P.O. Box 2411, Goleta, Calif. 93118

[21] Appl. No.: **202,679**
[22] Filed: **Jun. 6, 1988**
[51] **Int. Cl.**^{4} **A61N 5/00**
[52] **U.S. Cl.** **128/420.5**
[58] **Field of Search** .... 128/420.5, 804, 419 R, 128/421, 422, 746; 381/68

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,629,521 12/1971 Puharich et al. 128/402.5
3,766,331 10/1973 Zink 128/420.5

OTHER PUBLICATIONS

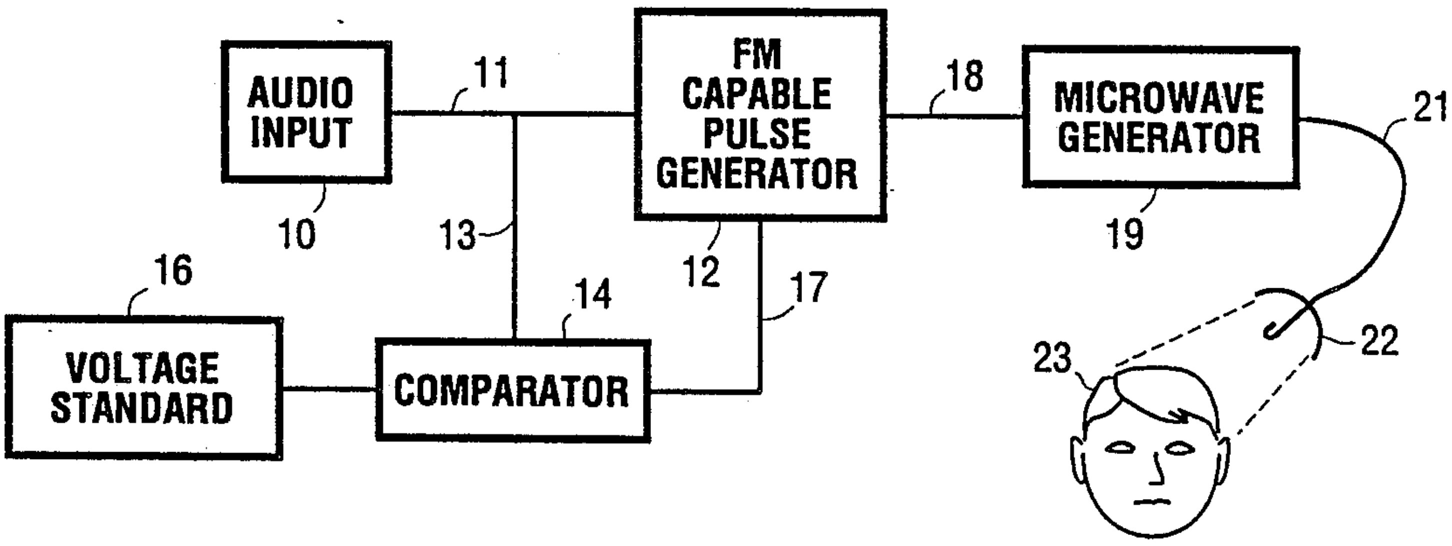
Cain et al, "Mammalian Auditory Responses . . . ", IEEE Trans Biomed Eng, pp. 288–293, 1978.
Frey et al, "Human Perception . . . Energy" Science, 181,356–358, 1973.
Jaski, "Radio Waves & Life", Radio-Electronics, pp. 45–45, Sep. 1960.
Microwave Auditory Effects and Applications, Lin, 1978, pp. 176–177.

Primary Examiner—Lee S. Cohen
Attorney, Agent, or Firm—Harry W. Brelsford

[57] **ABSTRACT**

Sound is induced in the head of a person by radiating the head with microwaves in the range of 100 megahertz to 10,000 megahertz that are modulated with a particular waveform. The waveform consists of frequency modulated bursts. Each burst is made up of ten to twenty uniformly spaced pulses grouped tightly together. The burst width is between 500 nanoseconds and 100 microseconds. The pulse width is in the range of 10 nanoseconds to 1 microsecond. The bursts are frequency modulated by the audio input to create the sensation of hearing in the person whose head is irradiated.

8 Claims, 1 Drawing Sheet



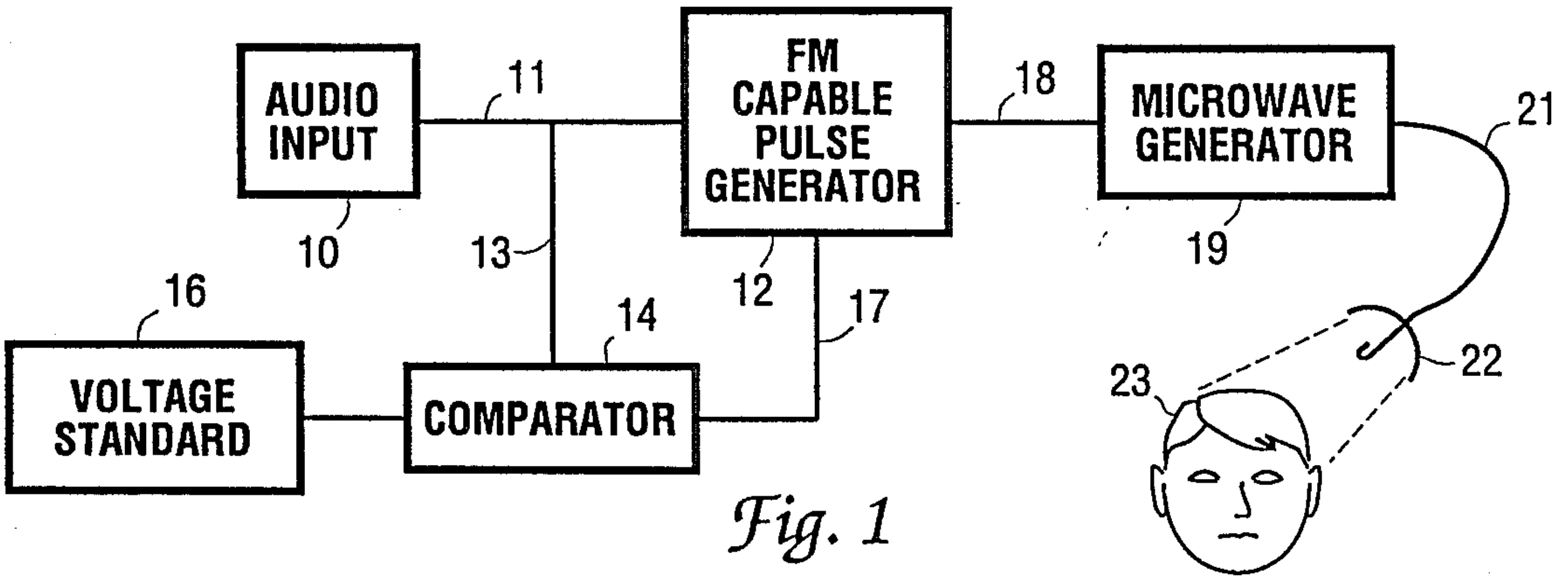


Fig. 1

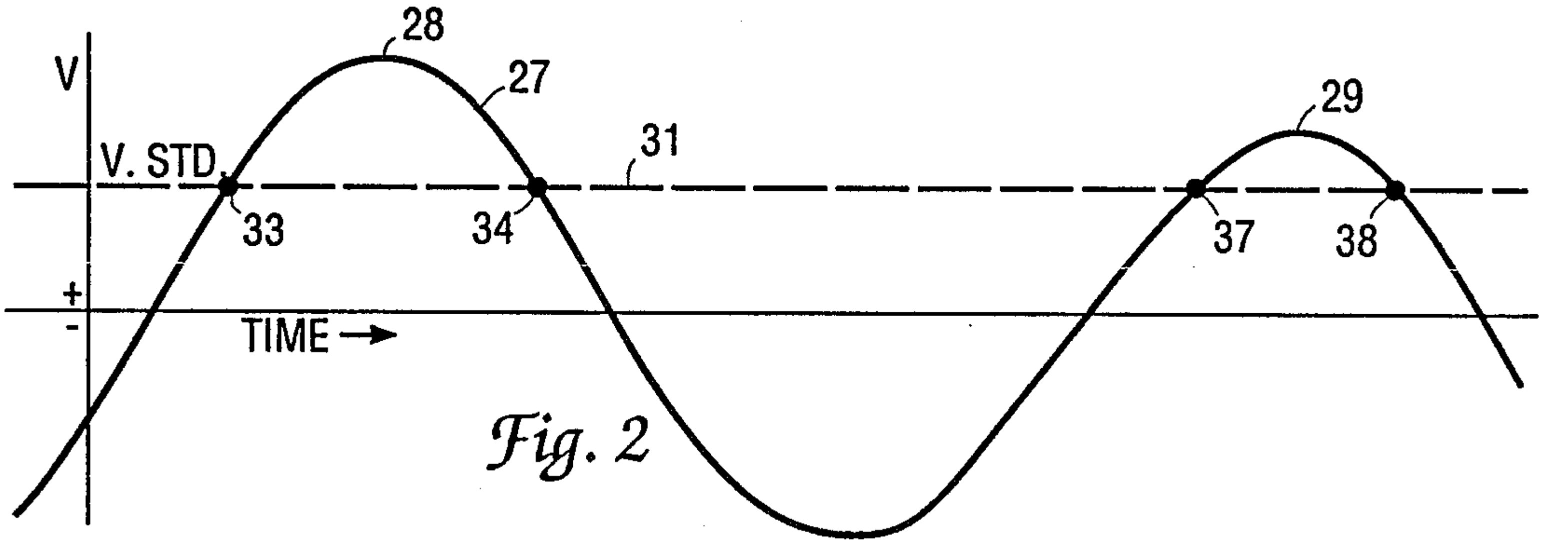


Fig. 2

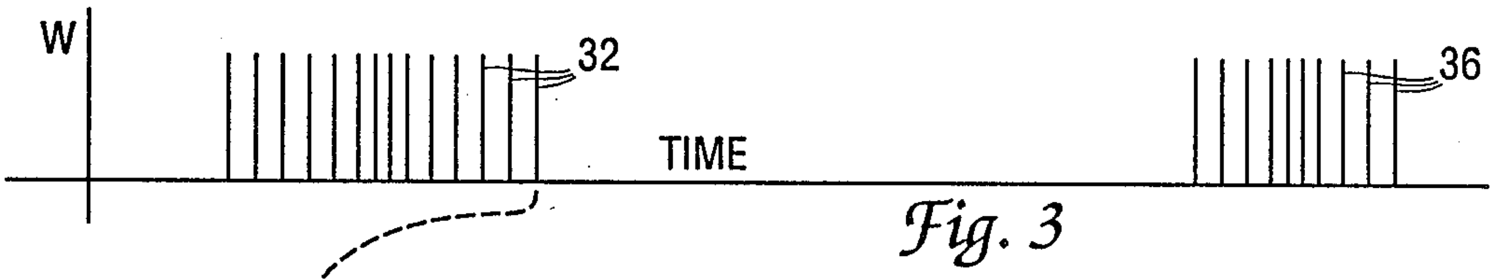


Fig. 3

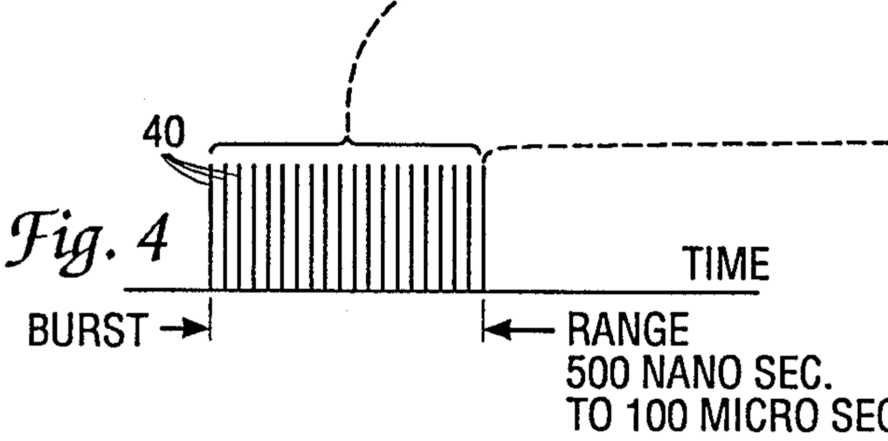


Fig. 4

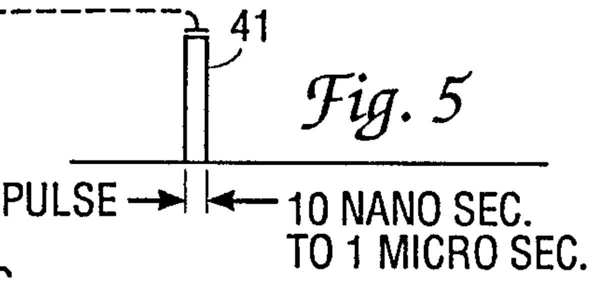


Fig. 5

HEARING SYSTEM

This invention relates to a hearing system for human beings in which high frequency electromagnetic energy is projected through the air to the head of a human being and the electromagnetic energy is modulated to create signals that can be discerned by the human being regardless of the hearing ability of the person.

THE PRIOR ART

Various types of apparatus and modes of application have been proposed and tried to inject intelligible sounds into the heads of human beings. Some of these have been devised to simulate speech and other sounds in deaf persons and other systems have been used to inject intelligible signals in persons of good hearing, but bypassing the normal human hearing organs.

U.S. Pat. No. 3,629,521 issued Dec. 21, 1971 describes the use of a pair of electrodes applied to a person's head to inject speech into the head of a deaf person. An oscillator creates a carrier in the range of 18 to 36 KHz that is amplitude modulated by a microphone.

Science magazine volume 181, page 356 describes a hearing system utilizing a radio frequency carrier of 1.245 GHz delivered through the air by means of a waveguide and horn antenna. The carrier was pulsed at the rate of 50 pulses per second. The human test subject reported a buzzing sound and the intensity varied with the peak power.

Similar methods of creating "clicks" inside the human head are reported in I.E.E.E. Transactions of Biomedical Engineering, volume BME 25, No. 3, May 1978.

The transmission of intelligible speech by audio modulated Microwave is described in the book Microwave Auditory Effects and Applications by James C. Lin 1978 publisher Charles C. Thomas.

BRIEF SUMMARY OF THE INVENTION

I have discovered that a pulsed signal on a radio frequency carrier of about 1,000 megahertz (1000 MHz) is effective in creating intelligible signals inside the head of a person if this electromagnetic (EM) energy is projected through the air to the head of the person. Intelligible signals are applied to the carrier by microphone or other audio source and I cause the bursts to be frequency modulated. The bursts are composed of a group of pulses. The pulses are carefully selected for peak strength and pulse width. Various objects, advantages and features of the invention will be apparent in the specification and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings forming an integral part of this specification:

FIG. 1 is a block diagram of the system of the invention.

FIG. 2 is a diagram of an audio wave which is the input to be perceived by the recipient.

FIG. 3 is a diagram on the same time coordinate as FIG. 2 showing bursts that are frequency modulated by the wave form of FIG. 2.

FIG. 4 shows, on an enlarged time coordinate, that each vertical line depicted in FIG. 3 is a burst of pulses. (A burst is a group of pulses).

FIG. 5 shows, on a further enlarged time coordinate, a single continues pulse, Depicted as'a vertical line in FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

Inasmuch as microwaves can damage human tissue, any projected energy must be carefully regulated to stay within safe limits. The guideline for 1,000 MHz, set by the American Standards Institute, is 3.3 mw/cm2 (3.3 milliwatts per square centimeter). The apparatus described herein must be regulated to stay within this upper limit.

Referring to FIG. 1 a microphone **10** or other generator of audio frequencies, delivers its output by wire **11** to an FM capable pulse generator **12** and by branch wire **13** to a comparator **14**. The comparator **14** also receives a signal from a voltage standard **16**. When the peak voltage of the audio generator **10** falls below the standard **16** the comparator delivers a signal by wire **17** to the FM capable pulse generator **12** to shut down the pulse generator **12**. This avoids spurious signals being generated. The output of the FM pulse generator **12** is delivered by wire **18** to a microwave generator **19** which delivers its output to the head of a human being **23**. In this fashion the person **23** is radiated with microwaves that are in short bursts.

The microwave generator **19** operates at a steady frequency presently preferred at 1,000 megahertz (1,000 million). I presently prefer to pulse the microwave energy at pulse widths of 10 nanoseconds to 1 microsecond. For any one setting of the FM capable generator **12**, this width is fixed. The pulses are arranged in bursts. The timing between bursts is controlled by the height of the audio envelope above the voltage standard line. In addition the bursts are spaced from one another at a non-uniform rate of 1 to 100 KHz. This non-uniform spacing of bursts is created in the FM capable generator **12**.

Referring to FIG. 2 there is illustrated an audio wave **27** generated by the audio input **10** wherein the horizontal axis is time and the vertical axis is voltage. For illustrative purposes the wave **27** is shown as having a voltage peak **28** on the left part of FIG. 2 and a voltage peak **29** of the right side of FIG. 2. The voltage standard **16** of FIG. **1** generates a dc voltage designated at **31** in FIG. 2. This standard voltage is preferably at about 50% of the peak voltage **28**. The comparator **14** of FIG. **1** actuates the FM capable generator **12** only when the positive envelope of the audio wave **27** exceeds the voltage standard. The negative portions of the audio wave are not utilized.

Referring now to FIG. **3** there is illustrated two groups of bursts of microwave energy that are delivered by the antenna **22** of FIG. **1** to the head of the person **23**. FIG. **3** has a horizontal time axis identical to the time axis of FIG. 2 and has a vertical axis that in this case represents the power of the microwaves from generator **19**. At the left part of FIG. **3** are a plurality of microwave bursts **32** that occur on the time axis from the point of intersection of the standard voltage **31** with the positive part of the audio wave **27**, designated as the time point **33** to time point **34** on FIG. 2. It will be noted in FIG. **3** that the bursts **32** are non-uniform in spacing and that they are closer together at the time of maximum audio voltage **28** and are more spread out toward the time points **33** and **34**. This is the frequency modulation effected by the FM pulse generator **12**.

Referring to the right part of FIG. 3 there are a plurality of microwave bursts **36** that are fewer in number and over a shorter time period than the pulses **32**. These extend on the time axis of FIG. **2** from point **37** to point **38**. These bursts **36** are also frequency modulated with the closest groupings appearing opposite peak **29** of FIG. **2** and greater spacing near time points **37** and **38**.

Referring now to FIG. **4** there is illustrated the fact that a single burst shown as straight lines **32** or **36** on FIG. **3** are made up of ten to twenty separate microwave pulses. The duration of the burst is between 500 nanoseconds and 100 microseconds, with an optimum of 2 microseconds. The duration of each pulse within the burst is 10 nanoseconds to 1 microsecond and a time duration of 100 nanoseconds is preferred. The bursts **32** of FIG. **3** are spaced non-uniformly from each other caused by the frequency modulation of **12**. FIG. **4** depicts a burst. Each vertical line **40** in FIG. **4** represents a single pulse. Each pulse is represented by the envelope **41** of FIG. **5**. The pulses within a burst are spaced uniformly from eachother. The spacing between pulses may vary from 5 nanoseconds to 10 microseconds.

Referring now to FIG. **3**, the concentration of bursts **32** opposite the peak **28** of FIG. **2** can be expressed as a frequency of repetition. I presently prefer to adjust the FM capable generator **12** to have a maximum frequency of repetition in the range of 25 Khz to 100 Khz. I deliberately keep this range low to reduce the amount of heating caused by the microwaves. The wider spacing of the pulses **32** opposite the cutoff points **33** and **34** of FIG. **2** can also be expressed as a frequency of reptition and I presently prefer a minimum repetition rate of 1 KHz. I find that this low repetition rate, altnough in the audio range, does not disrupt the transmission of auoio intelligence to the person **23**. The aim, again, is to reduce the amount of heat transmitted to the subject **23**.

OPERATION

Referring to FIG. **1**, the intelligence to be perceived by the person **23** is introduced at the audio source **10** which may be a microphone for voice, or a tape player for music, instruction, etc. This audio signal is transmitted to the FM capable generator **12** and to the comparator **14**. The comparator **14** compares the positive portions of the audio wave with voltage from the voltage standard **16** and when the audio wave instantaneously exceeds the standard voltage, the FM generator is actuated by the wire **17** connecting the comparator **14** and the FM generator **12**. The FM generator **12** then sends a plurality of signals to the microwave generator **19** at each peak of the audio wave above the voltage standard.

This is shown graphically in FIGS. **2-5**. The audio signal **27** of FIG. **2** exceeds the standard voltage **31** at point **33** whereupon the FM generator **12** starts emitting burst signals **32** at its lowest frequency of about 1 Khz. As time progresses past point **33** the voltage above the standard increases and the FM generator **12** responds by making the burst signals closer together until at peak **28** the maximum density of burst signals **32** is achieved, for example at a frequency of 50 Khz. The time duration of each pulse **40** (FIG. **4**) is also controlled by a fixed adjustment of the FM generator **12** and for example the duration may be 100 nanoseconds.

The frequency modulated burst signals are delivered by FM generator **12** to the microwave generator as interrupted dc and the microwave generator is turned on in response to each pulse **40** and its output is delivered by coaxial cable **21** to the parabolic antenna **22** to project microwaves onto the head of a person **23**. These microwaves penetrate the brain enough so that the electrical activity inside of the brain produces the sensation of sound. When the parameters are adjusted for the particular individual, he perceives intelligible audio, entirely independently of his external hearlng organs.

PRESENTLY PREFERRED QUANTITIES

As mentioned previously, I prefer rhat the standard voltage **31** of FIG. **2** be about 50% of peak audio voltage. This not only helps to reduce heating in the person **2** but also reduces spurious audio. This 50% is not vital and the useful range is 25% to 85% of peak audio.

The minimum burst repetition frequency (for example at time points **33** and **34**) is preferably 1 KHz and the maximum repetition frequency is in the range of 25 KHz to 100 KHz, with the lower frequencies resulting in less heating.

The time duration of each individual pulse of microwave radiation is in the range of 10 nanoseconds to 1 microsecond as indicated in FIG. **5**, with the shorter time periods resulting in less heating.

CONTROL OF POWER OUTPUT

As stated above, I maintain the power output of the parabolic antenna **22** within the present safe standard of 3.3 mw/cm2 (3.3 milliwatts per square centimeter). I control the power output by controlling the strengtn of the audio modulation. This results in a duty cycle of 0.005, the decimal measure of the time in any second that the transmitter is on full power. The peak power level can be between 500 mw and 5 w and at 0.005 duty cycle these peaks will result in an average power of 2.5 mw and 25 mw respectively. However, these values are further reduced by adjusting the audio modulation so that zero input produces a zero output. Since a voice signal, for example, is at maximum amplitude only a small fraction of the rime, the average power will be below the 3.3 mw/cm2 standard, even with 5 watts peak power.

THEORY OF OPERATION

I have not been able to experiment to determine how my microwave system works, but from my interpretation of prior work done in this field I believe that the process is as follows. Any group of bursts related to the audio ek **28** of FIG. **2** causes an increasing ultrasonic build up within the head of a human being starting with a low level for the first bursts pulses and building up to a high level with the last bursts pulses of a group. This buildup, I believe, causes the direct discharge of random brain neurons. These discharges at audio frequency create a perception of sound. This process, I believe, bypasses the normal hearing organs and can create sound in a person who is nerve-dead deaf. However, this theory of operation is only my guess and may prove to be in error in the future.

APPARATUS

The apparatus of FIG. **1** for carrying out my invention may include as a microwave generator Model PH40K of Applied Microwave Laboratories and described as Signal Source. The cable **21** connecting the microwave generator **19** and the antenna is RG8 coaxial cable by Belden Industries. The antenna **22** may be a standard parabolic antenna. The FM generator **12** has to be specially built to include the spacing runction which is obtained by a frequency generator built into a srandard FM generator.

I have described my invention witn respect to a presently preferred embodiment as required by the patent statutes. It will be apparent to those skilled in the technology that many variations, modification and additions can be made. All such variations, modifications and additions that come within the true spirit and scope of the invention are included in the claims.

I claim:

1. Apparatus for creating human hearing comprising:
(a) an audio source for creating electrical audio waves having positive peaks;
(b) a frequency modulator generator connected to the audio source to create frequency modulated bursts;
(c) a source of constant voltage to create a voltage standard that is in the range of 25% to 85% of the peak voltage of the audio waves;
(d) a comparator connected to the voltage source and the audio source to compare the instantaneous voltage of the waves from the audio source with the voltage standard;
(e) a connection of the comparator to the frequency modulator generator to activate the frequency modulator generator when the instantaneous voltage of the audio wave exceeds the standard voltage;
(f) a microwave generator creating microwaves in the range of 100 megahertz to 10,000 megahertz and connected to the frequency modulator generator, generating microwaves only when pulsed by the frequency modulator generator; and
(g) an antenna connected to the microwave generator to radiate the head of a human being to produce the sounds of the audio source.

2. Apparatus as set forth in claim **1** wherein the frequency generating range of the frequency modulator generator is 1 Khz to 100 KHz for bursts and 100 KHz to 20 MHZ for pulses within a burst.

3. Apparatus as set forth in claim **1** wherein the frequency generating range of the frequency modulator generator is one Khz to 100 KHz for bursts and 100 KHz to 20 MHZ for pulses within a burst and the duration of each pulse of the frequency modulator generator is in the range of 10 nanoseconds to 1 microsecond.

4. Apparatus as set forth in claim **1** wherein the voltage standard is approximately 50% of the peak of the audio waves.

5. Apparatus as set forth in claim **1** wherein the antenna is of the type that projects the microwaves in space to the head of a person.

6. Apparatus for creating human hearing comprising:
(a) an oscillator creating an electromagnetic carrier wave at a selected frequency in the range of 100 Mhz to 10,000 Mhz;
(b) a pulse generator connected to said oscillator to pulse the carrier with pulses having a width in the range of 10 nanoseconds to 1 microsecond with a minimum spacing between pulses of about 25 nanoseconds;
(c) a frequency modulator connected to the pulse generator;
(d) an audio signal generator connected to the modulator which modulates the pulses in accordance with the audio signal; and
(e) a transmitting antenna connected to the oscillator to transmit the carrier wave as thus modified to project the electromagnetic energy through space to the head of a person.

7. Apparatus as set forth in claim **6** wherein the modulator is a frequency modulator to vary the density of bursts within an audio envelope as a function of the audio amplitude.

8. The method of irradiating a person's head to produce sound in the head of the person comprising
(a) irridiating the head of a person with microwaves in the range of 100 Mhz to 10,000 Mhz;
(b) pulsing said microwaves with pulses in the range of 10 nanoseconds to 1 microsecond; and
(c) frequency modulating groups of pulses called bursts by audio waves wherein the modulation extends from 1 Khz to 100 Khz.

* * * * *

US007629918B2

(12) **United States Patent**
Brown et al.

(10) **Patent No.: US 7,629,918 B2**
(45) **Date of Patent: Dec. 8, 2009**

(54) **MULTIFUNCTIONAL RADIO FREQUENCY DIRECTED ENERGY SYSTEM**

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(73) Assignee: **Raytheon Company**, Waltham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 300 days.

(21) Appl. No.: **11/300,876**

(22) Filed: **Dec. 15, 2005**

(65) **Prior Publication Data**

US 2007/0139247 A1 Jun. 21, 2007

(51) **Int. Cl.**
G01S 13/66 (2006.01)
G01S 7/38 (2006.01)

(52) **U.S. Cl.** **342/13**; 342/67; 342/74; 342/90; 342/97; 89/1.11

(58) **Field of Classification Search** 244/54–61, 244/3.11–3.3; 342/13, 67, 74, 54, 90, 43, 342/729, 61, 14
See application file for complete search history.

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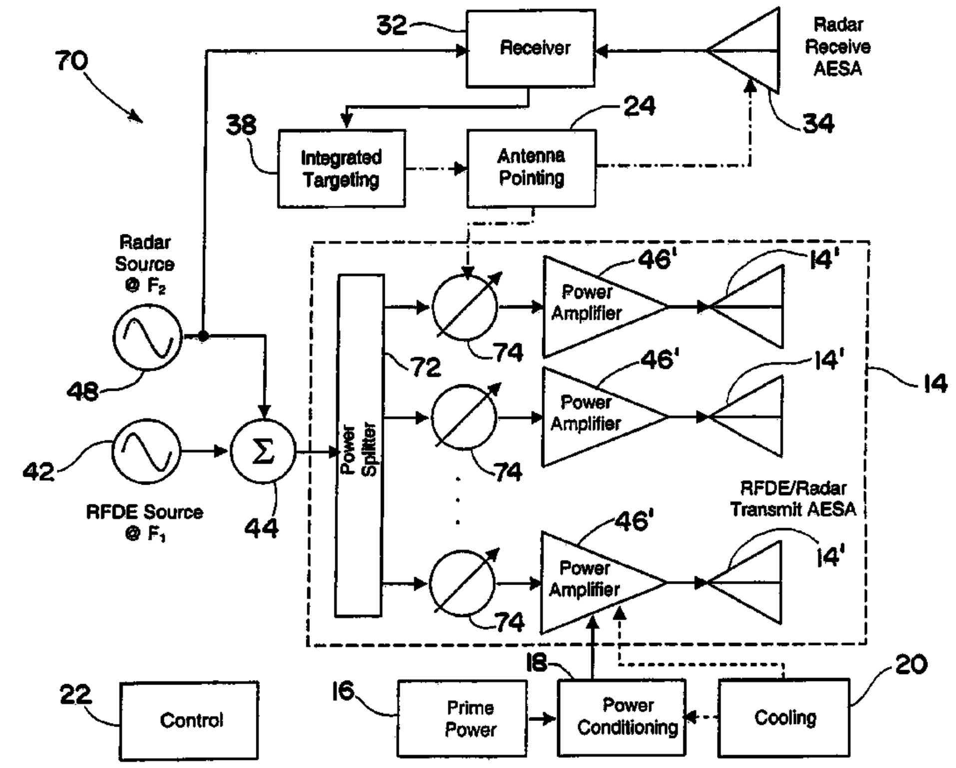
Primary Examiner—Thomas H Tarcza
Assistant Examiner—Matthew M Barker
(74) *Attorney, Agent, or Firm*—Renner, Otto, Boisselle & Sklar, LLP

(57) **ABSTRACT**

An RFDE system includes an RFDE transmitter and at least one RFDE antenna. The RFDE transmitter and antenna direct high power electromagnetic energy towards a target sufficient to cause high energy damage or disruption of the target. The RFDE system further includes a targeting system for locating the target. The targeting system includes a radar transmitter and at least one radar antenna for transmitting and receiving electromagnetic energy to locate the target. The RFDE system also includes an antenna pointing system for aiming the at least one RFDE antenna at the target based on the location of the target as ascertained by the targeting system. Moreover, at least a portion of the radar transmitter or the at least one radar antenna is integrated within at least a portion of the RFDE transmitter or the at least one RFDE antenna.

22 Claims, 8 Drawing Sheets



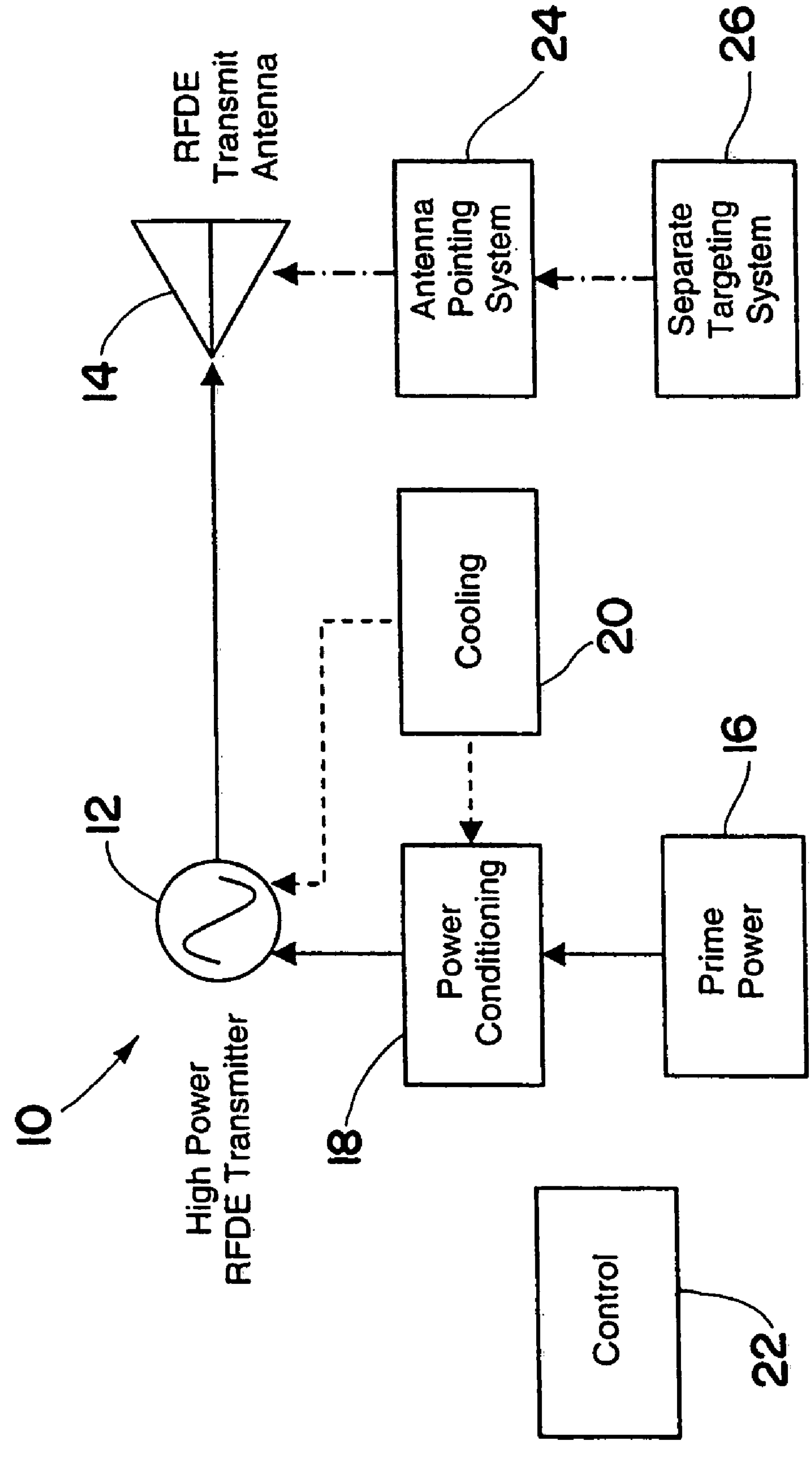


FIG. 1
Conventional Art

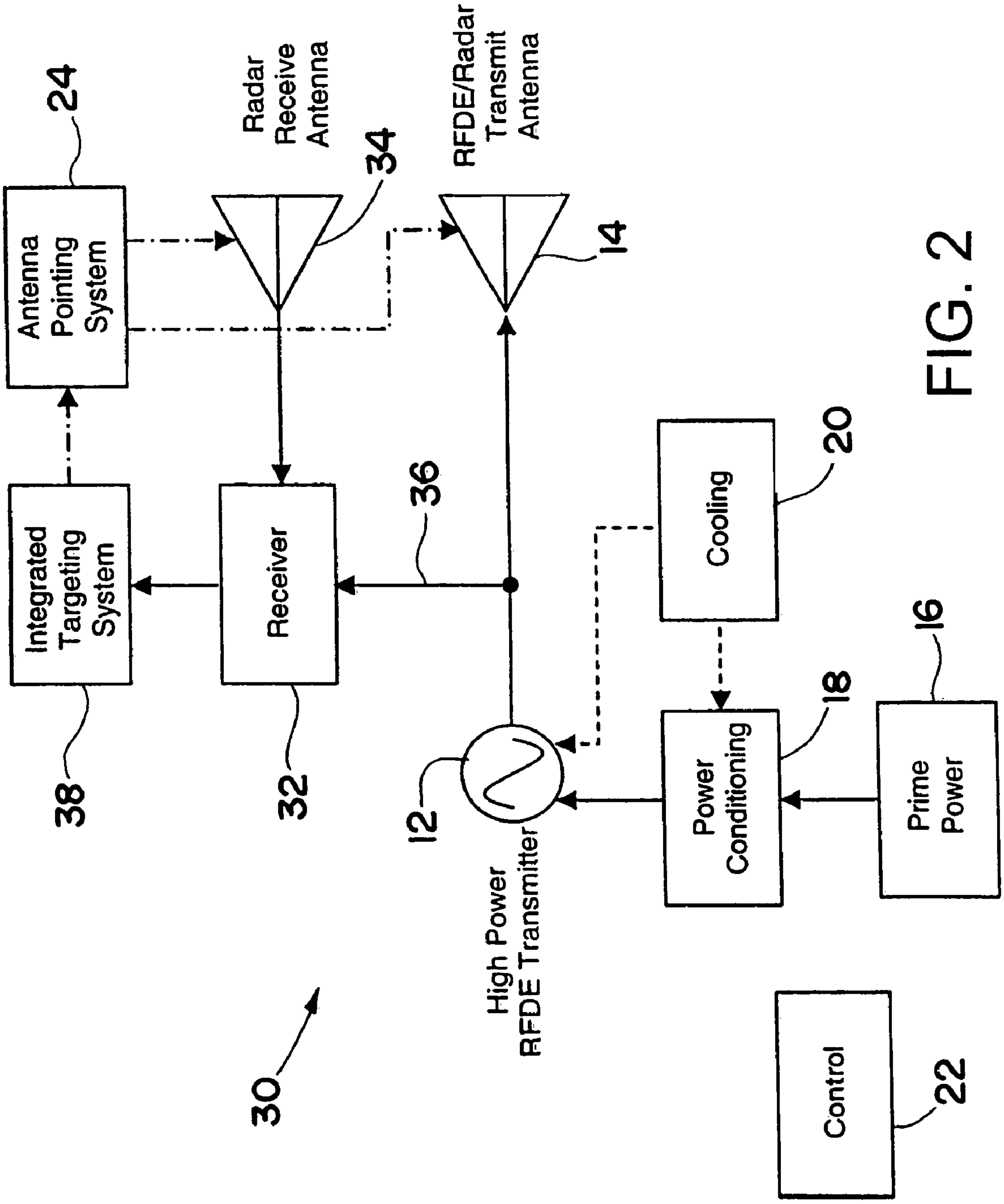

24
Antenna Pointing System
Radar Receive Antenna
34
RFDE/Radar Transmit Antenna
14
Integrated Targeting System
38
Receiver
32
36
Cooling
20
High Power RFDE Transmitter
12
Power Conditioning
18
Prime Power
16
30
Control
22

FIG. 2

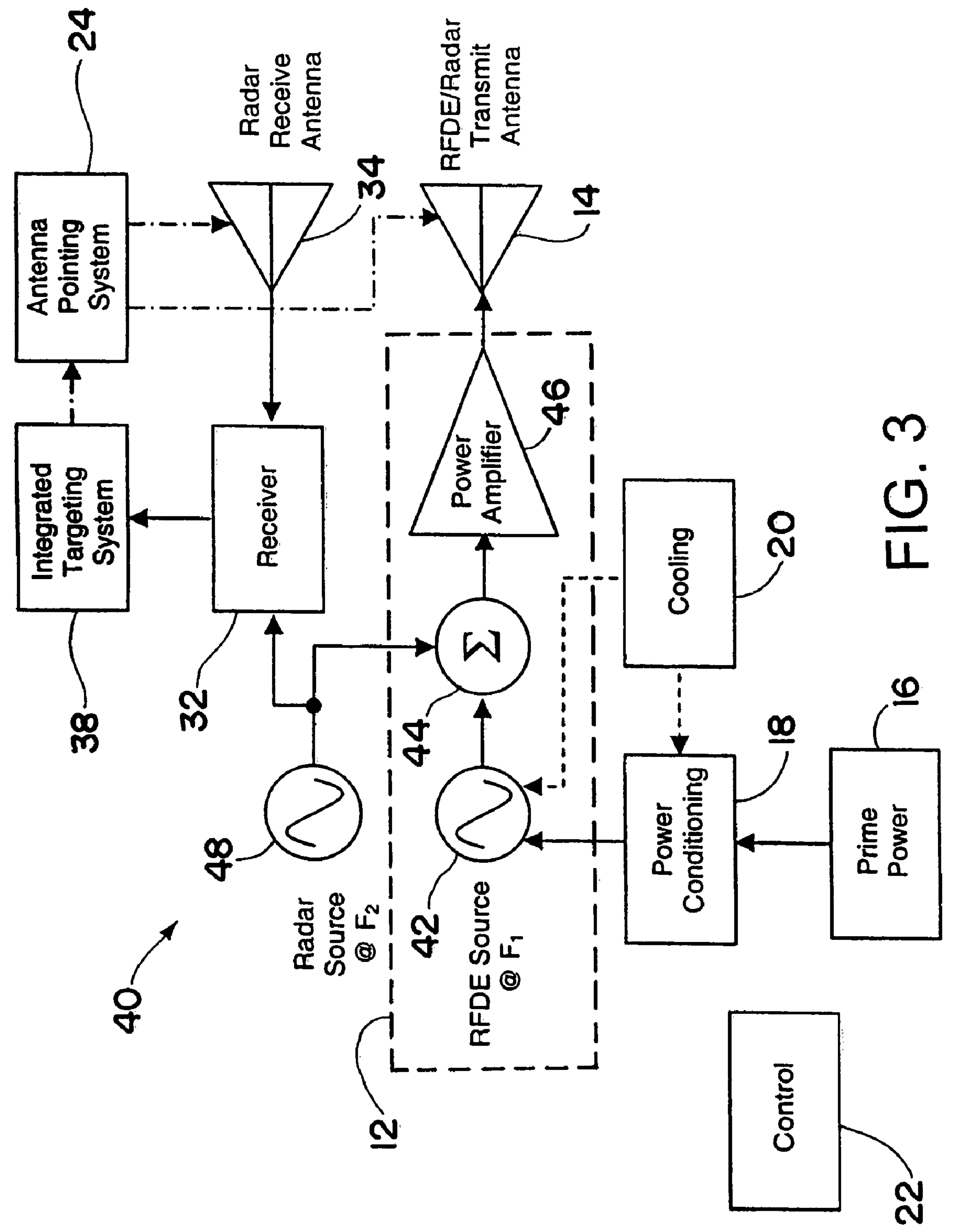

Antenna Pointing System
24
Radar Receive Antenna
34
RFDE/Radar Transmit Antenna
14
Integrated Targeting System
38
Receiver
32
Power Amplifier
46
Σ
44
Radar Source @ F_2
48
RFDE Source @ F_1
42
40
12
Cooling
20
Power Conditioning
18
Prime Power
16
Control
22

FIG. 3

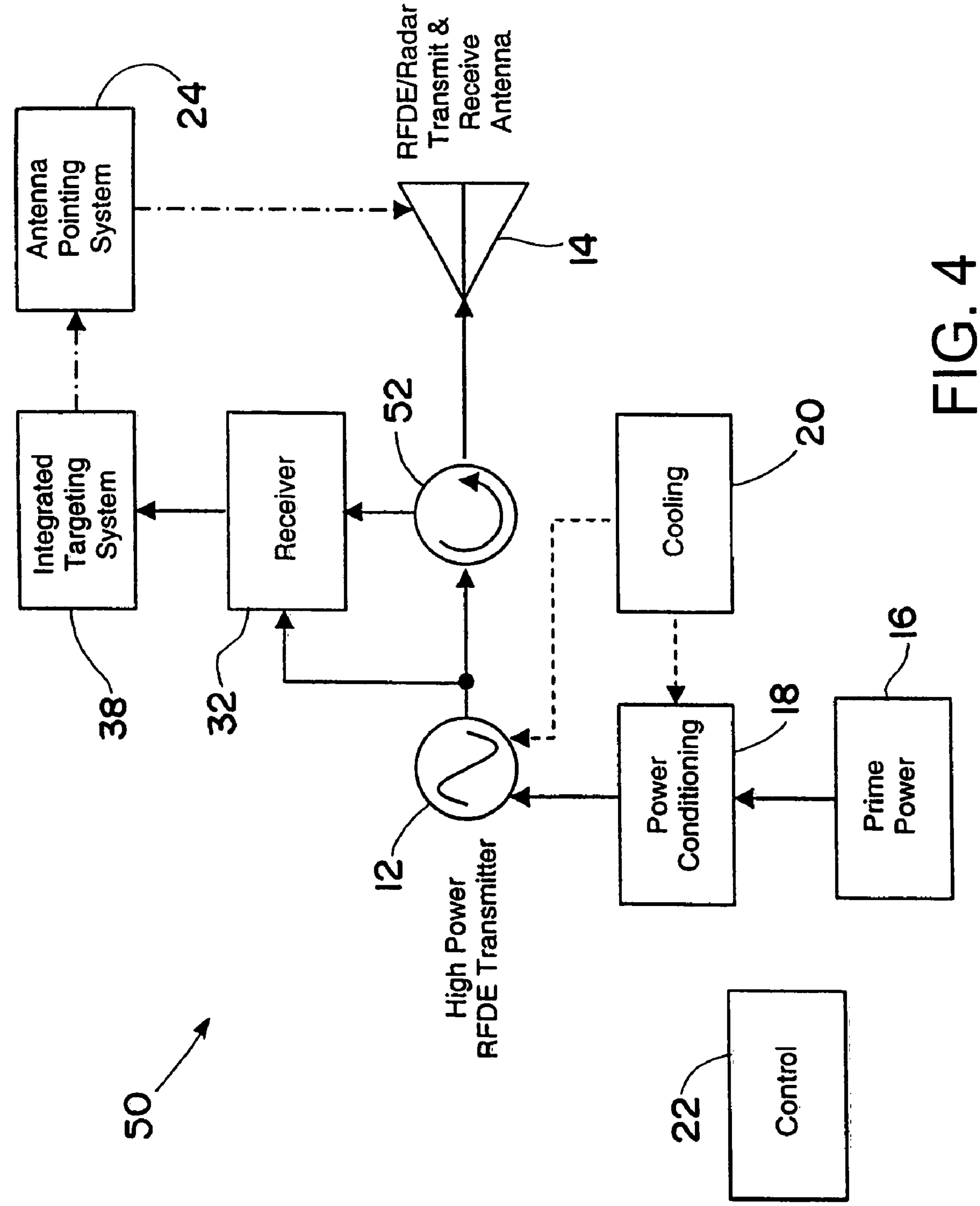

Antenna Pointing System
24
RFDE/Radar Transmit & Receive Antenna
14
Integrated Targeting System
38
Receiver
32
52
Cooling
20
High Power RFDE Transmitter
12
Power Conditioning
18
Prime Power
16
50
Control
22

FIG. 4

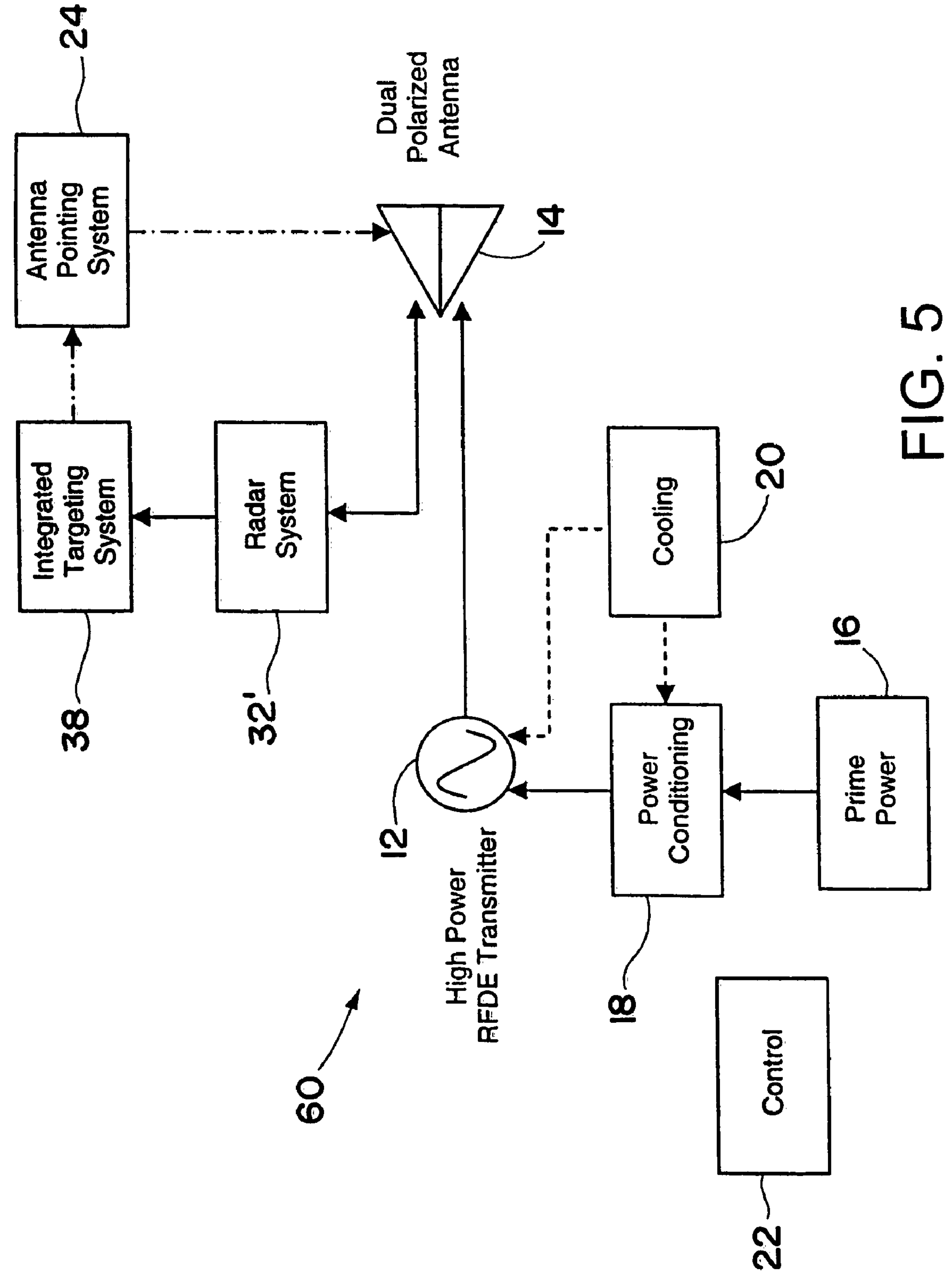

24
Antenna Pointing System
Dual Polarized Antenna
14
Integrated Targeting System
38
Radar System
32'
Cooling
20
16
Power Conditioning
Prime Power
12
High Power RFDE Transmitter
18
60
Control
22

FIG. 5

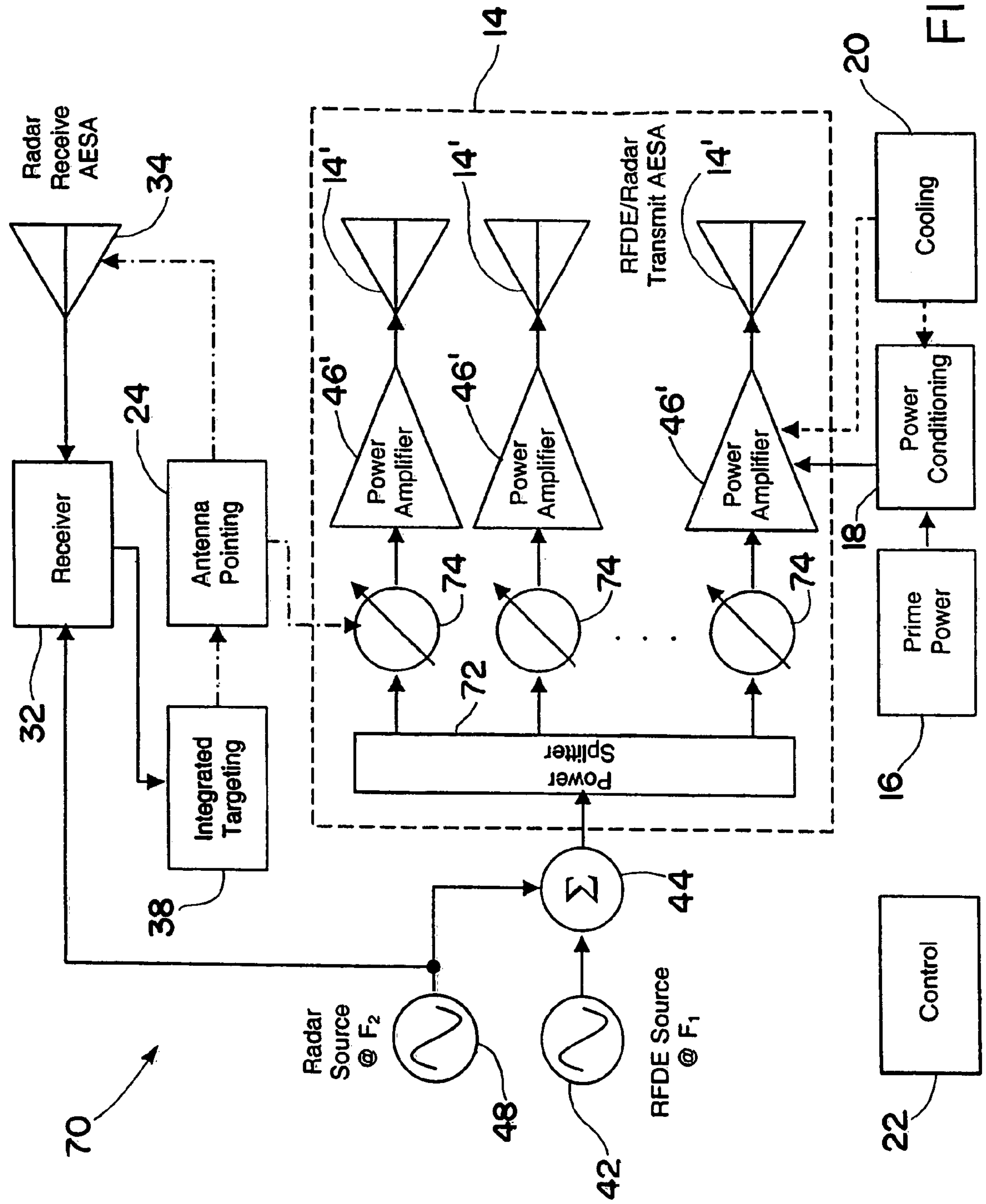

70
Radar Receive AESA
34
Receiver
32
Antenna Pointing
24
Integrated Targeting
38
14
14'
14'
RFDE/Radar Transmit AESA
14'
46'
Power Amplifier
46'
Power Amplifier
46'
Power Amplifier
74
74
74
72
Power Splitter
Σ
44
Radar Source @ F_2
48
RFDE Source @ F_1
42
Cooling
20
Power Conditioning
18
Prime Power
16
Control
22

FIG. 6

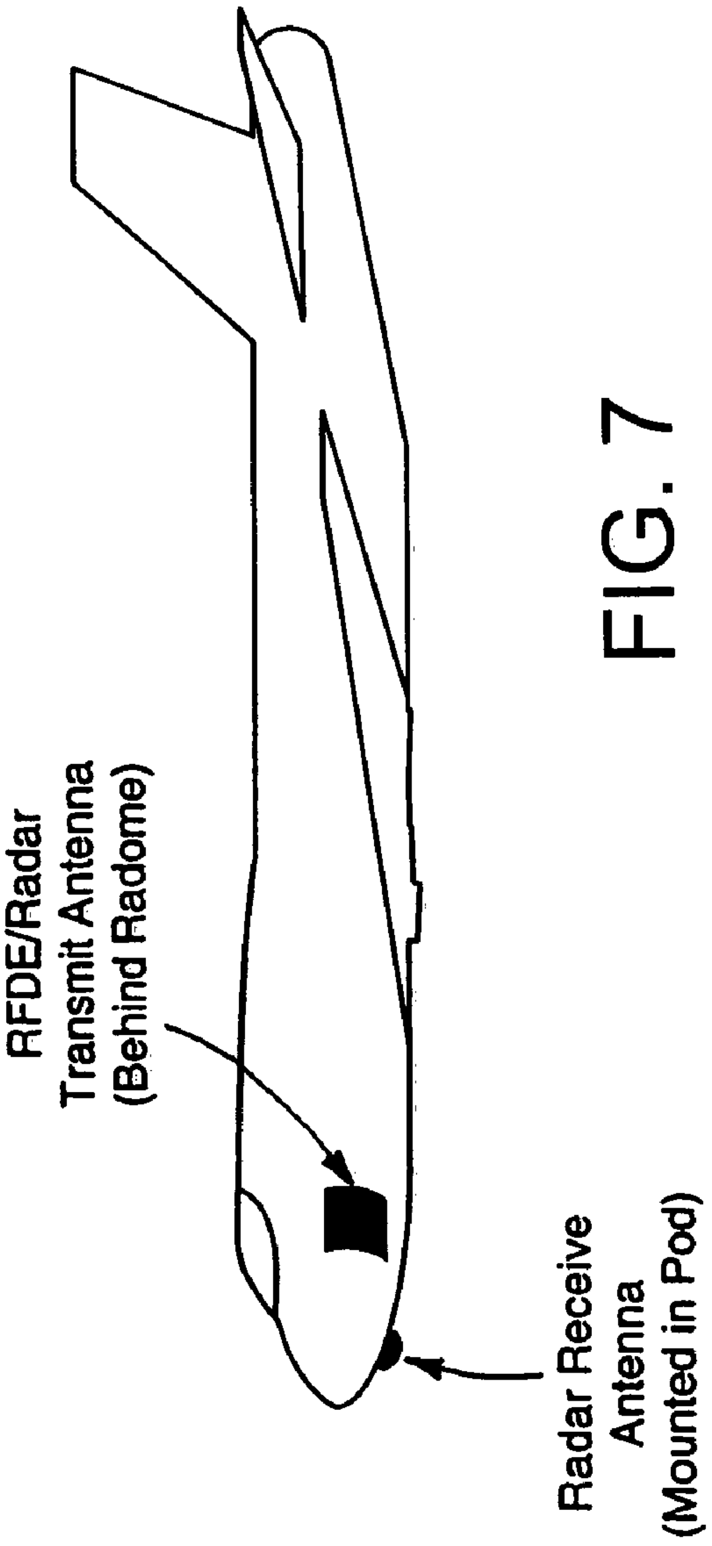

RFDE/Radar
Transmit Antenna
(Behind Radome)
Radar Receive
Antenna
(Mounted in Pod)

FIG. 7

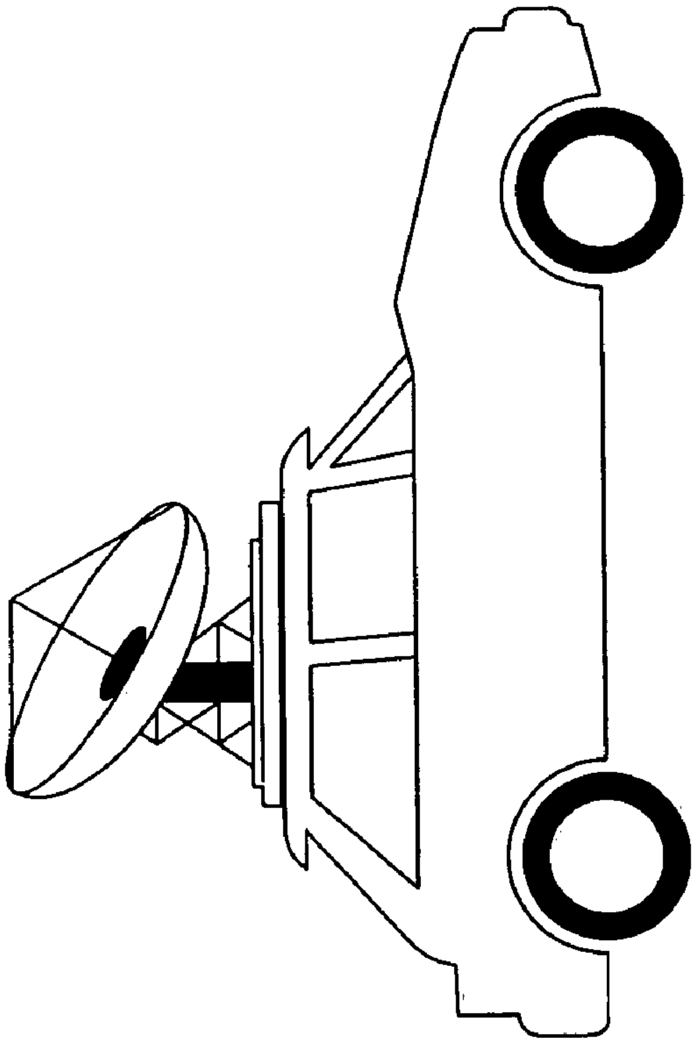


FIG. 8

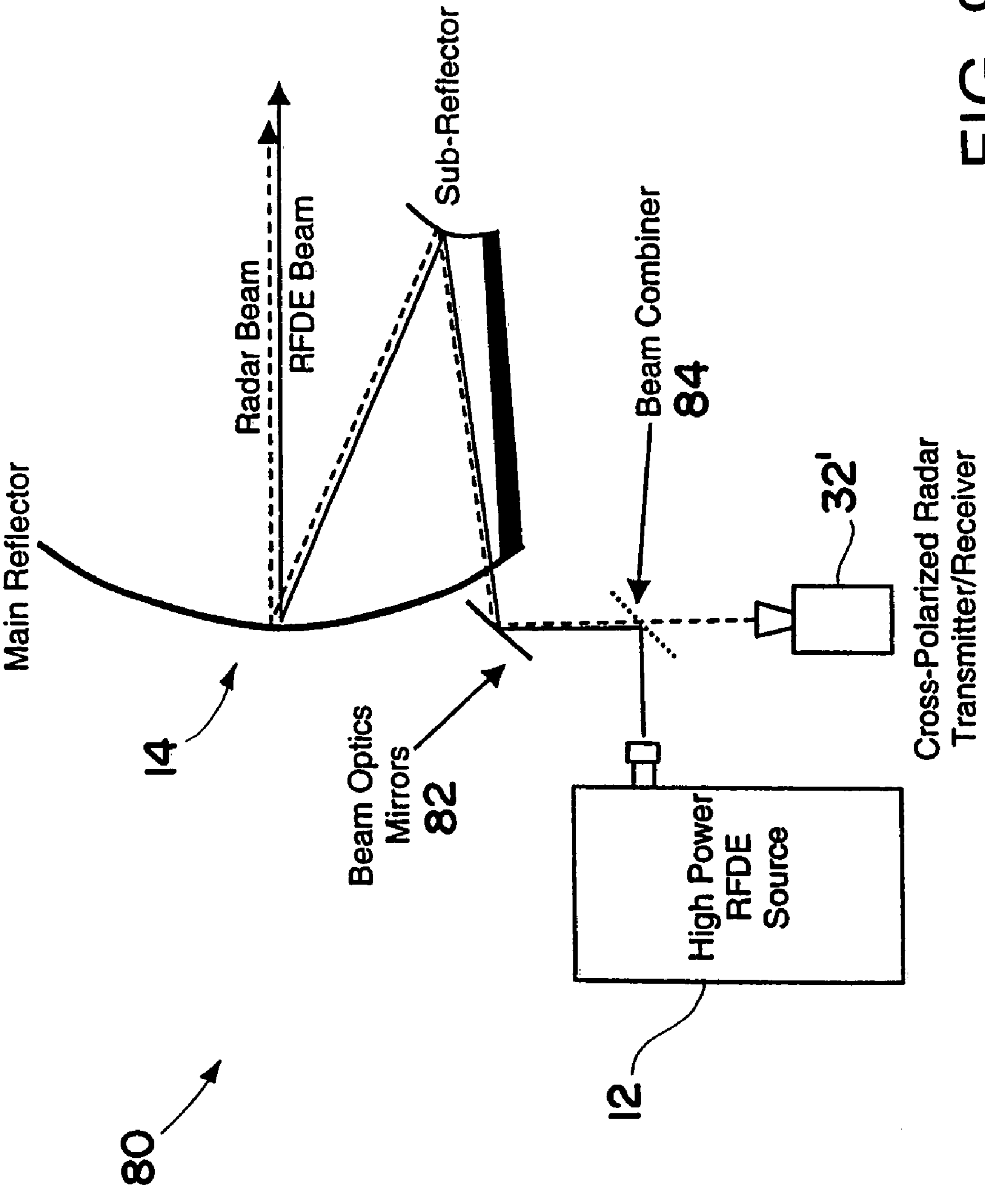

Main Reflector
Radar Beam
RFDE Beam
Sub-Reflector
Beam Combiner
84
32'
Cross-Polarized Radar Transmitter/Receiver
14
Beam Optics Mirrors
82
High Power RFDE Source
12
80

FIG. 9

MULTIFUNCTIONAL RADIO FREQUENCY DIRECTED ENERGY SYSTEM

TECHNICAL FIELD

The present invention relates generally to radio frequency directed energy (RFDE) systems, and more particularly to multifunctional type RFDE systems.

BACKGROUND OF THE INVENTION

Radio frequency directed energy (RFDE) systems are known in the art for directing high power RF, microwave and/or millimeter wave electromagnetic energy to destroy or disrupt a target. Although RFDE systems typically serve as military weapons, RFDE systems need not be limited to weapon systems. For example, RFDE systems of the present invention may be used for non-military purposes such as destroying or disrupting foreign objects, contaminants, undesirable atmospheric conditions, or other types of targets.

As for weapon systems, it is important to distinguish between an RFDE weapon system and an electronic warfare system. A primary difference between an RFDE weapon and an electronic warfare system is power and kill mode. An electronic warfare system makes use of a priori knowledge of a target it is designed to jam or disrupt. An electronic warfare system uses such a priori knowledge of a target's characteristics (e.g., frequency of operation, method of operation, etc.) to disrupt or confuse the target with "finesse", or a relatively low amount of power.

On the other hand, an RFDE weapon system can go after a broad range of targets (electronics, biological, ordinance, structures, etc.) due to its relatively large radiated power. A priori knowledge of the intended target characteristics is typically not required because the RFDE weapon either burns-out or overwhelms its target by the shear amount of power it radiates.

An ongoing problem with RFDE systems is targeting—accurately pointing the RF directed energy beam at the intended target and establishing an accurate range from the system to the target. To date, the RFDE system targeting problem has been addressed by using what may be referred to as auxiliary add-on systems. These add-on systems could include a stand-alone radar system, a stand-alone laser range finder, stand-alone optical or infrared imaging system, etc. However, these add-on systems add significant cost to the RFDE system. In addition, these add-on systems add significant complexity by requiring calibration of the alignment between the RFDE system and the stand-alone targeting system.

FIG. **1** is a block diagram of a typical RFDE system **10**. In its simplest form, the system **10** includes a high power transmitter **12** transmitting thru a high power antenna **14**. The transmitter **12** operates at RF, microwave or millimeter wave frequencies. The system **10** operates based on a prime power source **16**, such as an AC mains, generator, high capacity battery system, etc. A power conditioning block **18** conditions power delivered from the power source **16** so as to be suitable for powering the transmitter **12**. A cooling system **20** provides appropriate cooling to the power conditioning block **18** and the high power transmitter **12** as needed. A control block **22** provides appropriate control among the various sub-systems.

The RFDE weapon system **10** further includes an antenna pointing system **24** for aiming the high power antenna **14**, and thus the high power electromagnetic energy beam transmitted therefrom, at the target. The pointing system **24** typically is driven by coordinate data identifying the direction and range of the intended target. Such coordinate data is provided by a stand-alone targeting system **26**. As is noted above, the targeting system **26** is an add-on often in the form of a stand-alone radar system, a stand-alone laser range finder, stand-alone optical or infrared imaging system, etc. As is also noted above, however, these add-on systems add significantly to the cost and complexity of the RFDE system.

In view of the aforementioned shortcomings associated with conventional RFDE systems, there is a strong need in the art for an RFDE system which is not subject to the cost and complexity associated with conventional targeting systems.

SUMMARY OF THE INVENTION

The RFDE system of the present invention eliminates the need for a separate, stand-alone targeting system by integrating a targeting system within the RFDE system itself. The RFDE system is multi-functional in that all or part of the RFDE system hardware that functions to direct high power electromagnetic energy also functions to obtain and provide targeting information to aim the high power electromagnetic energy beam. For example, the RFDE transmitter is not only used as the source of the directed electromagnetic energy, but is also used as a radar transmitter for targeting an object. A relatively simple radar receiver may then be added to the RFDE system. The cost of the overall system is substantially reduced since an expensive radar transmitter is not required.

Moreover, the complexity of the system is reduced as calibration of the alignment between the RFDE system and a stand-alone targeting system becomes unnecessary.

According to one aspect of the invention, a multi-functional RFDE system is provided. The RFDE system includes an RFDE transmitter and at least one RFDE antenna. The RFDE transmitter and antenna direct high power electromagnetic energy towards a target sufficient to cause high energy damage or disruption of the target. The RFDE system further includes a targeting system for locating the target. The targeting system includes a radar transmitter and at least one radar antenna for transmitting and receiving electromagnetic energy to locate the target. The RFDE system also includes an antenna pointing system for aiming the at least one RFDE antenna at the target based on the location of the target as ascertained by the targeting system. Moreover, at least a portion of the radar transmitter or the at least one radar antenna is integrated within at least a portion of the RFDE transmitter or the at least one RFDE antenna.

According to another aspect of the invention, a method is provided operating an RFDE system. The method includes the steps of utilizing an RFDE transmitter and at least one RFDE antenna to direct high power electromagnetic energy towards a target sufficient to cause high energy damage or disruption of the target; utilizing a targeting system to locate the target, the targeting system including a radar transmitter and at least one radar antenna for transmitting and receiving electromagnetic energy to locate the target; aiming the at least one RFDE antenna at the target based on the location of the target as ascertained by the targeting system; and integrating at least at portion of the radar transmitter or the at least one radar antenna within, at least a portion of the RFDE transmitter or the at least one RFDE antenna.

To the accomplishment of the foregoing and related; ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative embodiments of the invention. These embodiments are indicative, however, of but a few of the various ways in which the principles of the invention may be employed. Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a conventional RFDE system;

FIG. **2** is a block diagram of a multi-functional RFDE system in accordance with a first embodiment of the present invention;

FIG. **3** is a block diagram of a multi-functional RFDE system in accordance with a second embodiment of the present invention;

FIG. **4** is a block diagram of a multi-functional RFDE system in accordance with a third embodiment of the present invention;

FIG. **5** is a block diagram of a multi-functional RFDE system in accordance with a fourth embodiment of the present invention;

FIG. **6** is a block diagram of a multi-functional RFDE system in accordance with a fifth embodiment of the present invention;

FIG. **7** illustrates a multi-functional RFDE system mounted within an aircraft in accordance with an embodiment of the present invention;

FIG. **8** illustrates a multi-functional RFDE system mounted within a wheeled vehicle in accordance with an embodiment of the present invention; and

FIG. **9** is a schematic diagram of a multi-functional RFDE system incorporating a reflector-type antenna in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described with reference to the drawings, in which like reference numerals are provided to refer to like elements throughout.

The RFDE system of the present invention integrates a targeting system, such as a radar targeting, system, into an otherwise conventional RFDE system. There are several ways that the targeting system can be integrated into the RFDE system as explained herein. The particular embodiments described below are meant to be merely exemplary. The present invention contemplates not only the particular embodiments described herein, but any system in which a targeting system is integrated in part or in whole within the RFDE system.

Referring to FIG. **2**, an RFDE system **30** is shown in accordance with an embodiment of the present invention. Since many of the elements of the RFDE system **30** in FIG. **3** are similar to those in the conventional system **10** discussed above with respect to FIG. **1**, only the relevant differences with be discussed herein for sake of brevity. In this particular embodiment, a portion of an otherwise conventional RFDE system (notably the high power transmitter **12** and/or the transmit antenna **14**) forms part of the targeting system. Specifically, during a targeting mode, the high power RFDE transmitter **12** is controlled by the control block **22** to transmit standard radar tracking signals thru the antenna **14**. The radar tracking signals may be any type of conventional radar signal such a pulse or continuous wave radar. The power level of the tracking signals may be a high powered signal, such as the RFDE signal itself, or a relatively low powered signal as more typical in radar tracking applications.

In the embodiment of FIG. **2**, a separate radar receiver **32** and radar receive antenna **34** are used in conjunction with the integrated RFDE/radar transmitter **12**. In one embodiment, the RFDE high power output beam intended to destroy or disturb a target is transmitted using the RFDE/radar transmitter **12** and antenna **14**. The radar receive antenna **34** receives portions of the RFDE output beam reflected by the target back towards the system **30**. The radar receiver **32** processes the reflected return signals using conventional techniques in order to identify the location of the target. For example, the radar receiver **32** can be coherently linked to the transmitted RFDE output waveform (represented by line **36**) so that Doppler processing can be achieved and the direction and range of the target identified.

The radar receiver **32** provides the target location information to an integrated targeting system block **38** which feeds the location information to the antenna pointing system **24**. Such operation allows the antenna **14** to be directed in both search and track radar functions.

As will be appreciated, the RFDE system **30** in FIG. **2**, as with the various other embodiments of the invention described herein, can operate in both an RFDE mode and a tracking mode. Both modes may be carried out simultaneously as described above, for example, where the high power electromagnetic energy output waveform of the RFDE system also serves as the radar tracking system transmit signal. Alternatively, the RFDE system **30** may switch between the RFDE mode and the tracking mode using a separate RFDE high power beam and lower power radar transmit signals, respectively. So long as the system **30** switches between the two modes rapidly enough so as not to lose track of the target, operation between RFDE mode and tracking mode may be time-division multiplexed.

Typically the radar transmitter is one of the most expensive portions of a radar tracking system. Therefore, by using the RFDE transmitter **12** and antenna **14** to function as the radar transmitter and antenna for targeting, the cost of the targeting system can be drastically reduced. Also, using the radar return of the RFDE high power beam itself to determine the target location can substantially improve the beam pointing accuracy of the RFDE system **30**. By using the RFDE high power beam to determine the location of the target, the power density on target will be maximized when standard radar tracking techniques are employed (e.g., monopulse, continuous scan, etc.).

Those of ordinary skill will appreciate that the RFDE transmitter **12** can be any transmitter suitable for transmitting an RFDE high power beam. For example, the RFDE transmitter **12** may be a single or multiple tube source, or solid state source. Moreover, it will be appreciated that the antenna **14** can be any type of suitable high power antenna which can be mechanically and/or electronically pointed and scanned via the antenna pointing system **24**. The transmitter/antenna can also be comprised of an active electronically steered array (AESA), for example, where an array of high power amplifiers/antennas is utilized. The radar receive antennas **34** can be any type of suitable antenna for receiving the radar return signals. As with the antenna **14**, the radar receive antenna **34** is mechanically and/or electronically pointed and scanned via the antenna pointing system **24**. The antenna pointing system **24** can be a mechanical gimbal or a beam steering computer controlling phase shifters in an electronically steerable array.

FIG. **3** illustrates another embodiment representing how a tracking system can be integrated with an RFDE system. The embodiment of FIG. **3**, as with the other embodiments described herein, shares many of the same elements as FIG. **2**, and thus again only the relevant differences between the embodiments will be discussed for sake of brevity.

Specifically, FIG. **3** illustrates an RFDE system **40** in which the power amplifier of the tracking system is integrated within the power amplifier of the RFDE system. More particularly, the RFDE transmitter **12** includes a low power RFDE signal source **42** operating at a first frequency and input to an adder **44**. The output of the adder **44** is input to a power amplifier **46** which amplifies the output before being radiated by the transmit antenna **14**. A low power radar signal source **48** at a second frequency is also input to the adder **44**. In addition, the low power radar signal source **48** is input to the radar receiver **32** to provide for coherent processing. The adder **44** thus outputs the combined RFDE signal source and radar signal source to the power amplifier **46**. The power amplifier **46** can be any suitable type of amplifier including, for example, an injection locked magnetron, a klystron, a solid-state amplifier, etc., or an array of any of these types of amplifiers in an AESA embodiment.

In the embodiment of FIG. **3**, a separate low power radar signal from the signal source **48** is used. This signal is combined with the RFDE signal from the RFDE signal source **42** prior to the combined signal being amplified by the power amplifier **46**. The frequencies of the RFDE signal and the radar signal do not have to be at the same frequency. In fact, they can be completely independent of each other within the bandwidth constraints of the power amplifier **46** and the RFDE transmit antenna **14**. It will be appreciated that significant isolation can be achieved between the RFDE and radar signals by filtering out the RFDE signal at the receive antenna **34** and/or radar receiver **32**.

Again, it will be appreciated that the RFDE system **40** of FIG. **3** may operate in an RFDE mode and a targeting mode. As in the other embodiments described herein, such modes may be carried out simultaneously or in time-multiplexed fashion. In the case where the RFDE signal source **42** and radar signal source **48** are different, one may consider such operation as frequency-multiplexed as will be appreciated.

FIG. **4** illustrates yet another embodiment of the present invention. In this embodiment, the RFDE system **50** integrates the radar receive antenna into the same antenna **14** serving as the RFDE and radar transmit antenna. This is accomplished by means of a high power circulator **52** which routes the RFDE/radar transmit signals from the shared transmitter **12** through to the antenna **14**. Reflected signals received by the antenna are routed by the circulator **52** to the receiver **32** for processing. In this example, as in the others discussed herein, the RFDE transmit signal may also be the radar transmit signal. The return signal is received by the same antenna **14** and coupled through the circulator **52** to the receiver **32**. The radar system thus can provide target information feedback to the antenna pointing system **24**.

The high power circulator **52** can be problematic in that it can be difficult to design a circulator that can handle the typical total power radiated by an RFDE system. Nevertheless, with improvements in materials and technologies such a circulator may someday be commercially feasible. Furthermore, the embodiment of FIG. **4** certainly is very suitable for an AESA system where the output power is broken-up among an array of transmit elements as discussed in more detail below.

In some integrated RFDE/targeting applications it may be desirable only to share the antenna between the RFDE and targeting systems. The RFDE system and the targeting system otherwise operate independently. An example of such an embodiment is shown in FIG. **5**.

Specifically, the embodiment of FIG. **5** illustrates a radar system **32'** which functions essentially independently of the RFDE system **60** with the exception of sharing a dual polarized antenna **14**. The RFDE system transmits the RFDE high power beam from the transmitter **12** via the dual polarized antenna **14** using one polarization (e.g., vertical, right hand circular, etc.). The radar system **32'**, with its own transmitter/receiver, transmits the radar transmit signal via the antenna **14** using the orthogonal polarization (e.g., horizontal, left hand circular, etc.). The reflected radar return signal received by the antenna **14** is processed by the radar system **32'** to provide target location information, again using conventional techniques. As in the other embodiments, the location information is provided to the integrated targeting system **38** which provides the information to the antenna pointing system **24**. The embodiment of FIG. **5** can be used to provide tracking information and/or is especially suitable for providing range information for the RFDE system.

FIG. **6** illustrates an embodiment in which AESAs or phased array antennas may be incorporated within the present invention. The embodiment of FIG. **6** is fundamentally the same as the embodiment of FIG. **3**, with the exception that the power amplifier **46** is represented by an array of power amplifiers **46'** included with the RFDE/radar transmit AESA antenna **14**. The radar receive antenna **34** may similarly comprise an AESA antenna.

As is shown in FIG. **6**, the combined signal from the adder **44** is input to a power splitter **72** within the AESA antenna **14**. The power splitter **72** separates the signal and provides the split signal to respective phase shifters **74** and power amplifiers **46'** corresponding to respective radiator elements **14'** in the antenna **14**. The antenna pointing system **24** may steer the antenna **14** by adjusting the phase of the phase shifters **74**, as will be appreciated.

Continuing to refer to FIG. **6**, it will further be appreciated that the radar source **48** and RFDE source **42** can be at different frequencies and still radiate in the same direction. As long as the phase shifters **74** are selected to provide a true time delay (which is fairly common in the art), the antenna **14** may be steered concurrently for both frequencies.

A multifunctional RFDE system of the present invention can be employed on a variety of platforms. For example, FIG. **7** illustrates an embodiment in which the system is employed on an aircraft. The combined RFDE/radar transmitter **12** and antenna **14** (not shown), for example, are mounted to radiate out the side of the aircraft. A pod is then mounted beneath the aircraft, containing the radar receiver **32** and receive antenna **34** (also not shown).

FIG. **8** shows an embodiment in which the RFDE system of the present invention can be employed on a wheeled vehicle. For example, the RFDE and radar systems are mounted in the back of the vehicle and share a common antenna. One possible such system **80** is shown in FIG. **9**. A high power RFDE source **12** radiates into a beam transport system comprised of mirrors (e.g., **82**) suitable for the frequency of operation. A cross-polarized radar transmit signal from the radar system **32'** is then injected into the RFDE beam path by means of a beam combiner/splitter **84**. The RFDE and radar transmit signal are then simultaneously transmitted from the common antenna **14**, in this embodiment a reflector-type antenna. The radar return signal is received by the antenna **14** and directed back to the cross-polarized radar system **32'** via the mirrors **82** and beam combiner/splitter **84**.

Although the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalents and modifications will occur to others skilled in the art upon the reading and understanding of the specification. For example, although the present invention has been described primarily in the context of a conventional radar based targeting system, other types of radar-like targeting systems which rely on the transmission and return of electromagnetic energy (e.g., laser-based, infrared, etc.) can also be used without departing from the scope of the invention.

The present invention includes all such equivalents and modifications, and is limited only by the scope of the following claims.

What is claimed is:

1. A multi-functional radio frequency directed energy (RFDE) system, comprising:

an RFDE transmitter and at least one RFDE antenna for directing high power electromagnetic energy towards a target sufficient to cause high energy damage or disruption of the target;

a targeting system for locating the target, the targeting system including a radar transmitter and at least one radar antenna for transmitting and receiving electromagnetic energy to locate the target; and

an antenna pointing system for aiming the at least one RFDE antenna at the target based on the location of the target as ascertained by the targeting system,

wherein at least a portion of the radar transmitter or the at least one radar antenna is integrated within at least a portion of the RFDE transmitter or the at least one RFDE antenna to provide simultaneous transmission of the high power electromagnetic energy and the electromagnetic energy to locate the target.

2. The multi-functional RFDE system of claim **1**, wherein the at least one radar antenna is embodied at least partially within the at least one RFDE antenna.

3. The multi-functional RFDE system of claim **1**, wherein the radar transmitter is embodied at least partially within the RFDE transmitter.

4. The multi-functional RFDE system of claim **3**, wherein the radar transmitter and the RFDE transmitter comprise a common RF power amplifier.

5. The multi-functional RFDE system of claim **4**, wherein the electromagnetic energy for locating the target is at a first frequency, and the high power electromagnetic energy is at a second frequency different from the first.

6. The multi-functional RFDE system of claim **1**, wherein the at least one radar antenna functions to transmit the electromagnetic energy for locating the target, and the at least one radar antenna is embodied at least partially in the at least one RFDE antenna.

7. The multi-functional RFDE system of claim **6**, wherein the at least one radar antenna includes a first radar antenna that functions to transmit the electromagnetic energy for locating the target and to transmit the high power electromagnetic energy, and a second radar antenna that functions to receive the electromagnetic energy reflected from the target in order to locate the target.

8. The multi-functional RFDE system of claim **7**, wherein the first radar antenna comprises a multi-element phased array.

9. The multi-functional RFDE system of claim **6**, wherein the at least one radar antenna that functions to transmit the electromagnetic energy for locating the target also functions to receive the electromagnetic energy reflected from the target in order to locate the target.

10. The multi-functional RFDE system of claim **9**, wherein the at least one radar antenna comprises a dual-polarized antenna.

11. The multi-functional RFDE system of claim **1**, wherein the system comprises a beam combiner for combining the high power electromagnetic energy with the electromagnetic energy for locating the target in a path between the RFDE transmitter and the RFDE antenna.

12. The multi-functional RFDE system of claim **1**, wherein the system is configured for operation in a mobile vehicle.

13. The multi-functional RFDE system of claim **12**, wherein the mobile vehicle is a wheeled-vehicle.

14. The multi-functional RFDE system of claim **12**, wherein the mobile vehicle is an aircraft.

15. A method of operating a multi-functional radio frequency directed energy (RFDE) system, comprising the steps of:

utilizing an RFDE transmitter and at least one RFDE antenna to direct high power electromagnetic energy towards a target sufficient to cause high energy damage or disruption of the target;

utilizing a targeting system to locate the target, the targeting system including a radar transmitter and at least one radar antenna for transmitting and receiving electromagnetic energy to locate the target;

aiming the at least one RFDE antenna at the target based on the location of the target as ascertained by the targeting system; and

integrating at least a portion of the radar transmitter or the at least one radar antenna within at least a portion of the RFDE transmitter or the at least one RFDE antenna to provide simultaneous transmission of the high power electromagnetic energy and the electromagnetic energy to locate the target.

16. The method of claim **15**, wherein the at least one radar antenna is embodied at least partially within the at least one RFDE antenna.

17. The method of claim **15**, wherein the radar transmitter is embodied at least partially within the RFDE transmitter.

18. The method of claim **17**, wherein the radar transmitter and the RFDE transmitter comprise a common RF power amplifier.

19. The method of claim **18**, wherein the electromagnetic energy for locating the target is at a first frequency, and the high power electromagnetic energy is at a second frequency different from the first.

20. The method of claim **15**, wherein the at least one radar antenna functions to transmit the electromagnetic energy for locating the target, and the at least one radar antenna is embodied at least partially in the at least one RFDE antenna.

21. A multi-functional radio frequency directed energy (RFDE) system, comprising:

an RFDE transmitter and at least one RFDE antenna for directing high power electromagnetic energy towards a target sufficient to cause high energy damage or disruption of the target;

a targeting system for locating the target, the targeting system including a radar transmitter and at least one radar antenna for transmitting and receiving electromagnetic energy to locate the target; and

an antenna pointing system for aiming the at least one RFDE antenna at the target based on the location of the target as ascertained by the targeting system,

wherein at least a portion of the radar transmitter or the at least one radar antenna is integrated within at least a portion of the RFDE transmitter or the at least one RFDE antenna and the high power electromagnetic energy is used as the electromagnetic energy to locate the target.

22. A method of operating a multi-functional radio frequency directed energy (RFDE) system, comprising the steps of:

utilizing an RFDE transmitter and at least one RFDE antenna to direct high power electromagnetic energy towards a target sufficient to cause high energy damage or disruption of the target;

utilizing a targeting system to locate the target, the targeting system including a radar transmitter and at least one radar antenna for transmitting and receiving electromagnetic energy to locate the target;

aiming the at least one RFDE antenna at the target based on the location of the target as ascertained by the targeting system; and

integrating at least a portion of the radar transmitter or the at least one radar antenna within at least a portion of the RFDE transmitter or the at least one RFDE antenna,

wherein the high power electromagnetic energy is used as the electromagnetic energy to locate the target.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,629,918 B2
APPLICATION NO. : 11/300876
DATED : December 8, 2009
INVENTOR(S) : Brown et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 230 days.

Signed and Sealed this

Second Day of November, 2010

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

US006587729B2

(12) **United States Patent**
O'Loughlin et al.

(10) **Patent No.: US 6,587,729 B2**
(45) **Date of Patent: Jul. 1, 2003**

(54) **APPARATUS FOR AUDIBLY COMMUNICATING SPEECH USING THE RADIO FREQUENCY HEARING EFFECT**

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(73) Assignee: **The United States of America as represented by the Secretary of the Air Force**, Washington, DC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/131,626**

(22) Filed: **Apr. 24, 2002**

(65) **Prior Publication Data**

US 2002/0123775 A1 Sep. 5, 2002

Related U.S. Application Data

(62) Division of application No. 08/766,687, filed on Dec. 13, 1996, now Pat. No. 6,470,214.

(51) **Int. Cl.**^{7} **H03C 1/54**
(52) **U.S. Cl.** **607/55**; 128/897; 332/167; 381/151; 600/586

(58) **Field of Search** 332/167; 381/151; 607/56, 55; 340/384.1; 600/559, 23, 586; 128/897, 898

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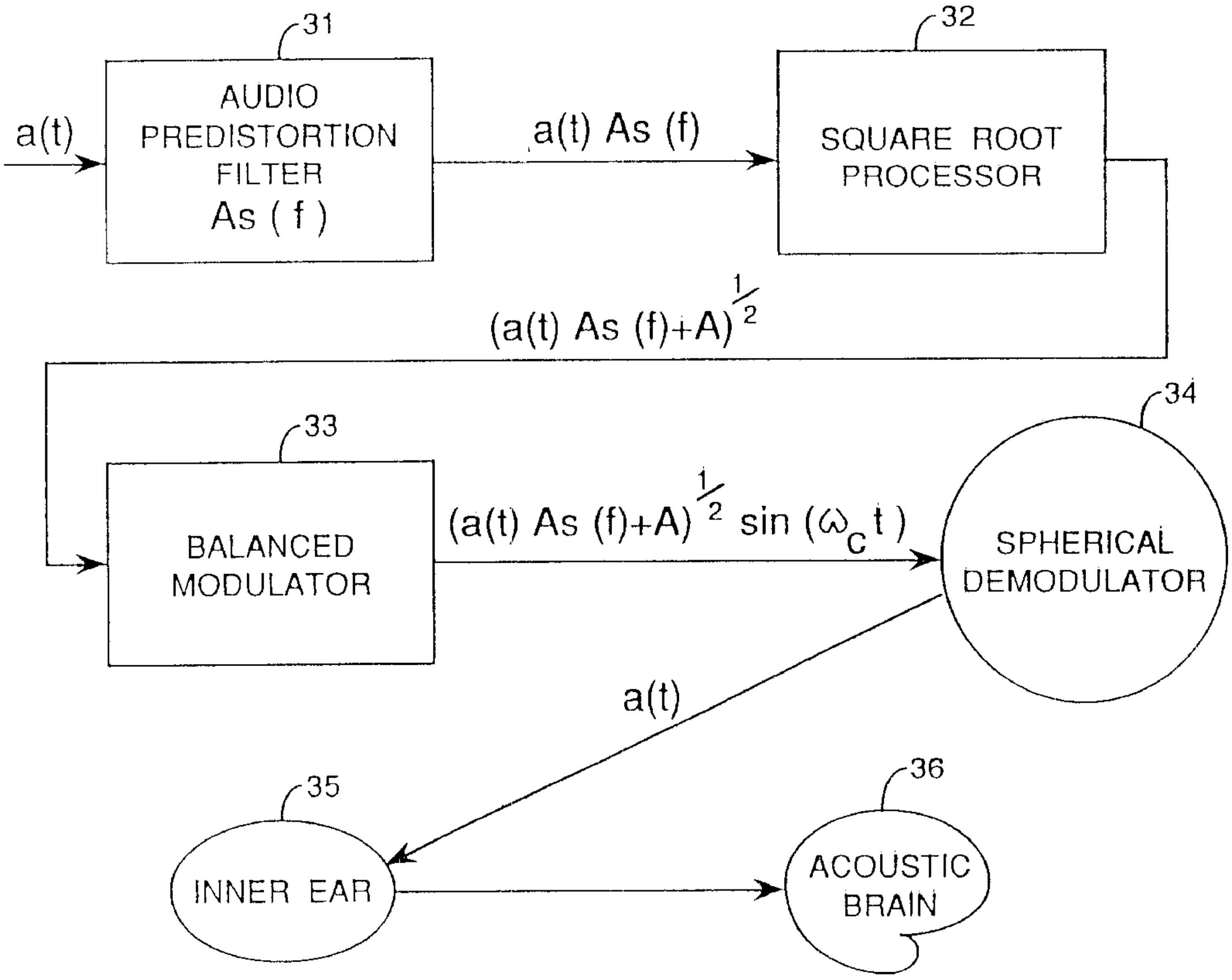
(57) **ABSTRACT**

A modulation process with a fully suppressed carrier and input preprocessor filtering to produce an encoded output; for amplitude modulation (AM) and audio speech preprocessor filtering, intelligible subjective sound is produced when the encoded signal is demodulated using the RF Hearing Effect. Suitable forms of carrier suppressed modulation include single sideband (SSB) and carrier suppressed amplitude modulation (CSAM), with both sidebands present.

11 Claims, 3 Drawing Sheets



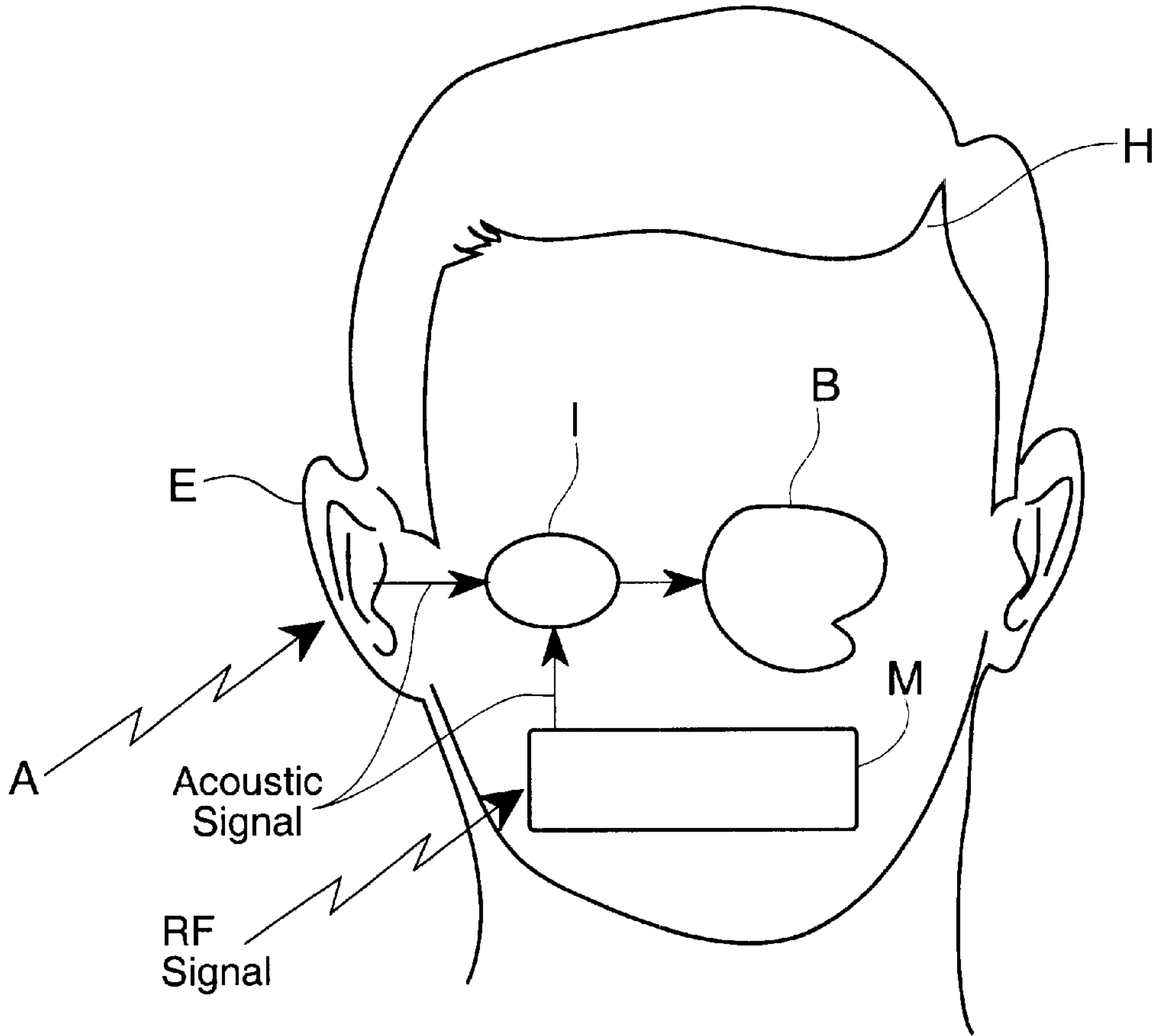


Fig. 1

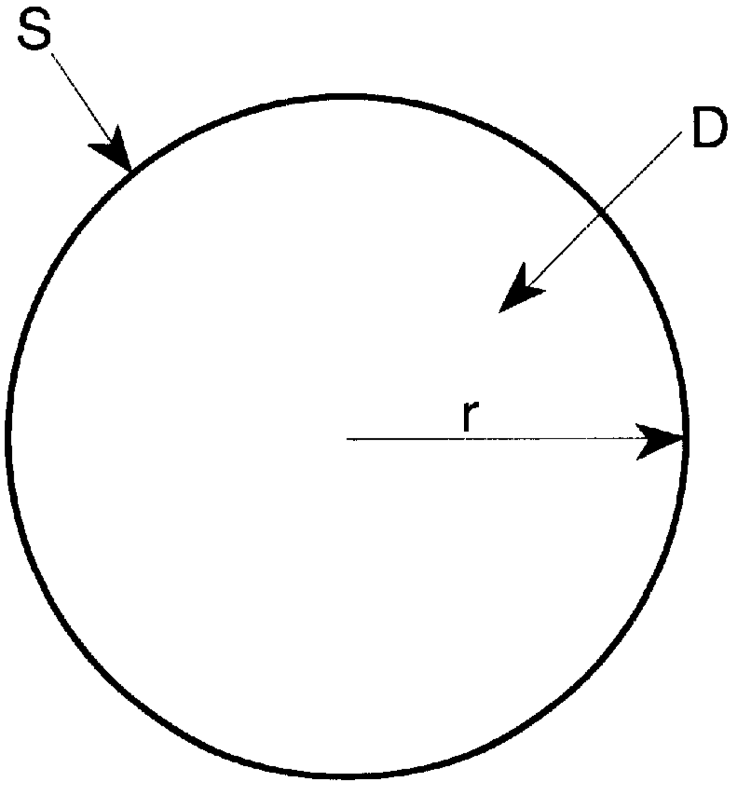


Fig. 2

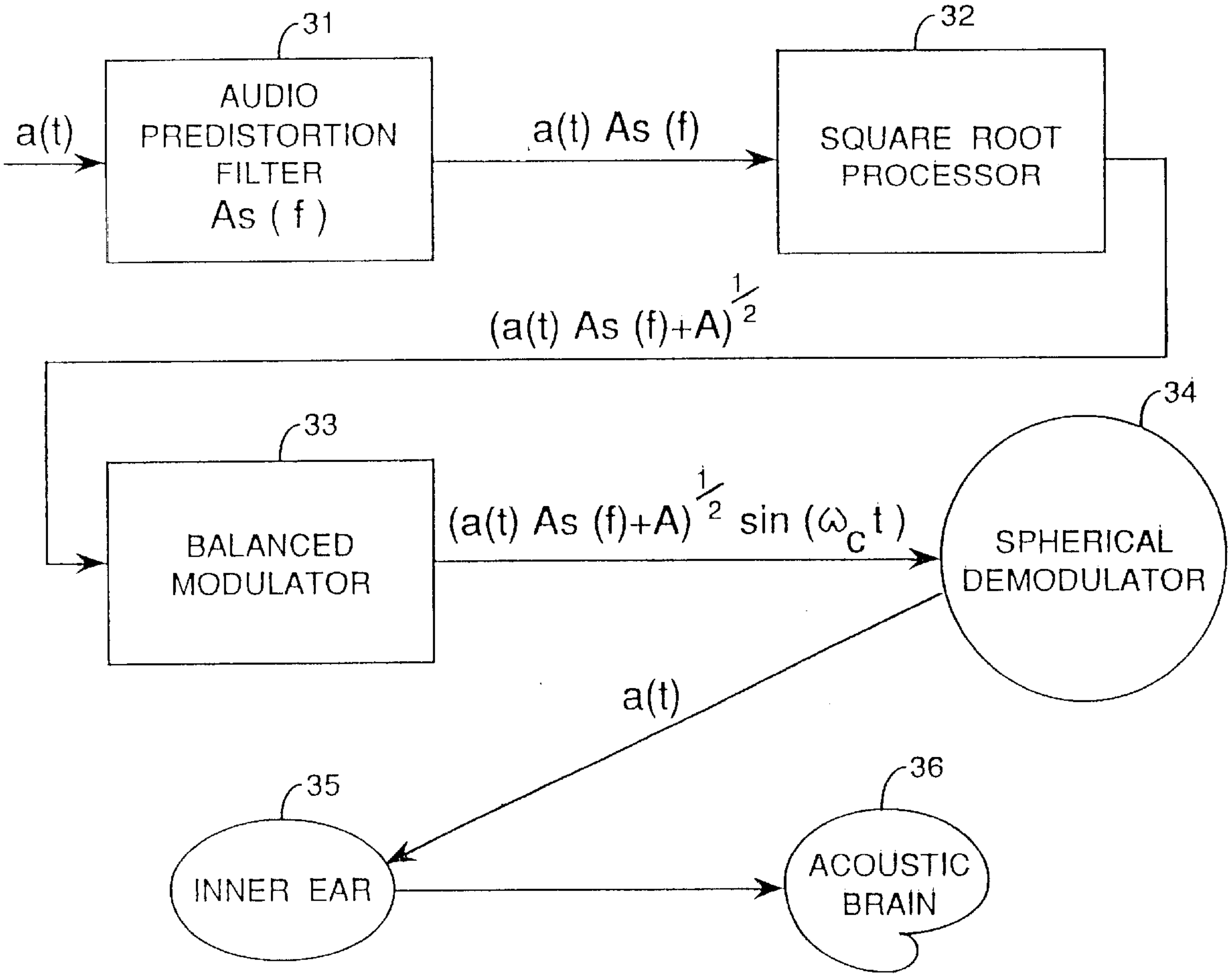

31
a(t)
AUDIO PREDISTORTION FILTER As (f)
a(t) As (f)
32
SQUARE ROOT PROCESSOR
(a(t) As (f)+A)^1/2
33
BALANCED MODULATOR
(a(t) As (f)+A)^1/2 sin (ωc t)
34
SPHERICAL DEMODULATOR
a(t)
35
INNER EAR
36
ACOUSTIC BRAIN

FIG. 3

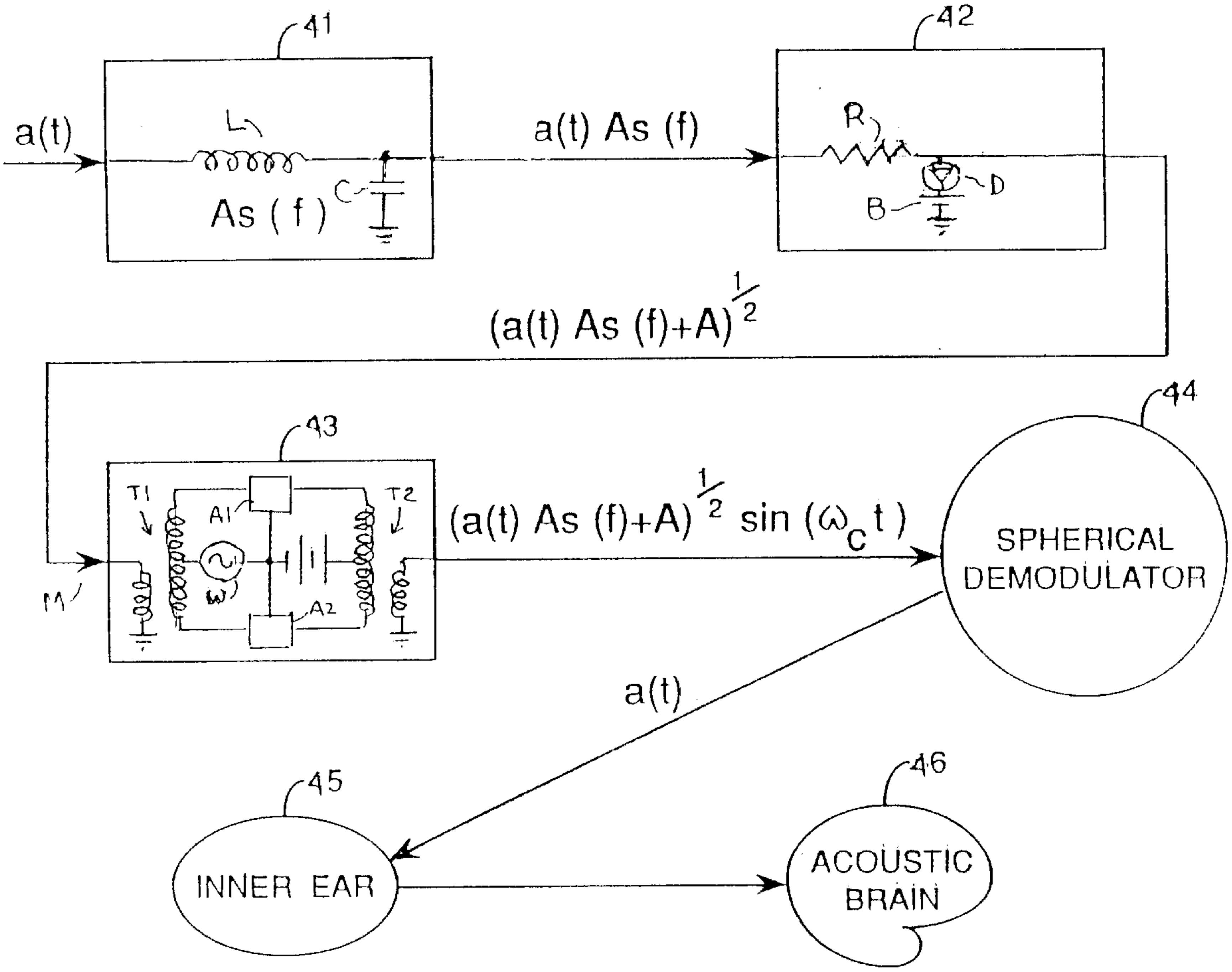

41
a(t)
L
As (f)
C
a(t) As (f)
42
R
D
B
(a(t) As (f)+A)^1/2
43
T1
A1
ω
T2
A2
M
(a(t) As (f)+A)^1/2 sin (ωc t)
44
SPHERICAL DEMODULATOR
a(t)
45
INNER EAR
46
ACOUSTIC BRAIN

FIG. 4

APPARATUS FOR AUDIBLY COMMUNICATING SPEECH USING THE RADIO FREQUENCY HEARING EFFECT

This application is a division of U.S. patent application Ser. No. 08/766,687 filed on Dec. 13, 1996, now U.S. Pat. No. 6,470,214, and claims the benefit of the foregoing filing date.

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

BACKGROUND OF THE INVENTION

This invention relates to the modulating of signals on carriers, which are transmitted and the signals intelligibly recovered, and more particularly, to the modulation of speech on a carrier and the intelligible recover of the speech by means of the Radio Frequency Hearing Effect.

The Radio Frequency ("RF") Hearing Effect was first noticed during World War II as a subjective "click" produced by a pulsed radar signal when the transmitted power is above a "threshold" level. Below the threshold level, the click cannot be heard.

The discovery of the Radio Frequency Hearing Effect suggested that a pulsed RF carrier could be encoded with an amplitude modulated ("AM") envelope. In one approach to pulsed carrier modulation, it was assumed that the "click" of the pulsed carrier was similar to a data sample and could be used to synthesize both simple and complex tones such as speech. Although pulsed carrier modulation can induce a subjective sensation for simple tones, it severely distorts the complex waveforms of speech, as has been confirmed experimentally.

The presence of this kind of distortion has prevented the click process for the encoding of intelligible speech. An example is provided by AM sampled data modulation

Upon demodulation the perceived speech signal has some of the envelope characteristics of an audio signal. Consequently a message can be recognized as speech when a listener is pre-advised that speech has been sent. However, if the listener does not know the content of the message, the audio signal is unintelligible.

The attempt to use the click process to encode speech has been based on the assumption that if simple tones can be encoded, speech can be encoded as well, but this is not so. A simple tone can contain several distortions and still be perceived as a tone whereas the same degree of distortion applied to speech renders it unintelligible.

SUMMARY OF THE INVENTION

In accomplishing the foregoing and related object the invention uses a modulation process with a fully suppressed carrier and pre-processor filtering of the input to produce an encoded output. Where amplitude modulation (AM) is employed and the pre-processor filtering is of audio speech input, intelligible subjective sound is produced when the encoded signal is demodulated by means of the RF Hearing Effect. Suitable forms of carrier suppressed modulation include single sideband (SSB) and carrier suppressed amplitude modulation (CSAM), with both sidebands present.

The invention further provides for analysis of the RE hearing phenomena based on an RF to acoustic transducer model. Analysis of the model suggests a new modulation process which permits the RF Hearing Effect to be used following the transmission of encoded speech.

In accordance with one aspect of the invention the preprocessing of an input speech signal takes place with a filter that de-emphasizes the high frequency content of the input speech signal. The de-emphasis can provide a signal reduction of about 40 dB (decibels) per decade. Further processing of the speech signal then takes place by adding a bias level and taking a root of the predistorted waveform. The resultant signal is used to modulated an RF carrier in the AM fully suppressed carrier mode, with single or double sidebands.

The modulated RF signal is demodulated by an RF to acoustic demodulator that produces an intelligible acoustic replication of the original input speech.

The RF Hearing Effect is explained and analyzed as a thermal to acoustic demodulating process. Energy absorption in a medium, such as the head, causes mechanical expansion and contraction, and thus an acoustic signal.

When the expansion and contraction take place in the head of an animal, the acoustic signal is passed by conduction to the inner ear where it is further processed as if it were an acoustic signal from the outer ear.

The RF to Acoustic Demodulator thus has characteristics which permit the conversion of the RF energy input to an acoustic output.

Accordingly, it is an object of the invention to provide a novel technique for the intelligible encoding of signals. A related object is to provide for the intelligible encoding of speech.

Another object of the invention is to make use of the Radio Frequency ("RF") Hearing Effect in the intelligible demodulation of encoded signals, including speech.

Still another object of the invention is to suitably encode a pulsed RF carrier with an amplitude modulated ("AM") envelope such that the modulation will be intelligibly demodulated by means of the RF Hearing Effect. A related object is to permit a message to be identified and understood as speech when a listener does not know beforehand that the message is speech.

Other aspects of the invention will be come apparent after considering several illustrative embodiments, taken in conjunction with the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram model of RF to Acoustic Demodulation Process making use of the Radio Frequency ("RF") Hearing Effect;

FIG. **2** is a spherical demodulator and radiator having a specific acoustic impedance for demodulation using the RF Hearing Effect;

FIG. **3** is a diagram illustrating the overall process and constituents of the invention; and

FIG. **4** is an illustrative circuit and wiring diagram for the components of FIG. **3**.

DETAINED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the drawings, FIG. **1** illustrates the RF to acoustic demodulation process of the invention. Ordinarily an acoustic signal A reaches the outer ear E of the head H and traverses first to the inner ear I and then to the acoustic receptors of the brain B. A modulated RF signal, however, enters a demodulator D, which is illustratively provided by the mass M of the brain, and is approximated, as shown in FIG. **2**, by a sphere S of radius r in the head H. The radius r of the sphere S is about 7 cm to make the sphere S equivalent to about the volume of the brain B. It will be appreciated that where the demodulator D, which can be an external component, is not employed with the acoustic receptors of the brain B, it can have other forms.

The sphere S, or its equivalent ellipsoid or similar solid, absorbs RF power which causes an increase in temperature that in turn causes an expansion and contraction which results in an acoustic wave. As a first approximation, it is assumed that the RF power is absorbed uniformly in the brain. Where the demodulator D is external to the brain B, the medium and/or RF carrier frequency can be selected to assure sufficiently uniform absorption.

For the modulated RF signal of FIG. **1**, the power absorbed in the sphere S is proportional to the power waveform of the modulated RF signal. The absorption rate is characterized quantitatively in terms of the SAR (Specific Absorption Rate) in the units of absorbed watts per kilogram per incident watt per square centimeter.

The temperature of the sphere S is taken as following the integrated heat input from the power waveform, i.e. the process is approximated as being adiabatic, at least for short term intervals on the order of a few minutes.

The radial expansion of the sphere follows temperature and is converted to sound pressure, p(t), determined by the radial velocity (U_r) multiplied by the real part of the specific acoustic impedance (Z_s) of the sphere, as indicated in equation (1), below.

$$Z_s=\rho_o c(jkr)/(1+jkr)=\rho_o c\ jf/f_c/(1+jf/f_c) \quad (1)$$

Where:

ρ_o=density, 1000 kg/m^3 for water

c=speed of sound, 1560 m/s, in water @ 37° C.

k=wave number, 2π/wavelength

r=sphere radius, in meters (m)

f=audio frequency

f_c=lower cutoff break frequency,=c/(2πr)

j=the 90 degree phase-shift operator

The specific acoustic impedance for a sphere of 7 cm radius, on the order of the size of the brain, has a lower cut-off break frequency of about 3,547 Hertz (Hz) for the parameters given for equation (1). The essential frequency range of speech is about 300 to 3000 Hz, i.e., below the cut-off frequency. It is therefore the Real part (R_e) of Z_s times the radial particle velocity (U_r) which determines the sound pressure, p(t). The real part of Z_s is given by equation (1a), below:

$$R_e(Z_s)=\rho_o c(f/f_c)^2/(1+(f/f_c)^2) \quad (1a)$$

In the speech spectrum, which is below the brain cut-off frequency, the sphere S is an acoustic filter which "rolls off", i.e. decreases in amplitude at −40 dB per decade with decreasing frequency. In addition to any other demodulation processes to be analyzed below, the filter characteristics of the sphere will modify the acoustic signal with a 40 dB per decade slope in favor of the high frequencies.

Results for an AM Modulated Single Tone

An RF carrier with amplitude A_c at frequency ω_c is AM modulated 100 percent with a single tone audio signal at frequency ω_1. The voltage (time) equation of this modulated signal is given by equation (2), below:

$$V(t)=A_c \sin(\omega_c t)(1+\sin(\omega_a t)) \quad (2)$$

The power signal is $V(t)^2$ as given by equation (3), below:

$$P(t)=A_c^2[3/4+\sin(\omega_3 t)-1/4\cos(2\omega_3 t)-3/4\cos(2\omega_c t)-\cos(2\omega_c t)\sin(\omega_3 t)+1/4\cos(2\omega_c t)\cos(2\omega_3 t)] \quad (3)$$

To find the energy absorbed in the sphere, the time integral of equation (3) is taken times absorption coefficient, K. The result is divided by the specific heat, SH to obtain the temperature of the sphere and then multiplied by the volume expansion coefficient, Mv to obtain the change in volume. The change in volume is related to the change in radius by equation (4), below:

$$dV/V=3dr/r \quad (4)$$

To obtain the amplitude of the radius change, there is multiplication by the radius and division by three. The rms radial surface velocity, U_r is determined by multiplying the time derivative by r and dividing by $2^{1/2}$. The result, U_r, is proportional to the power function, P(t) in equation (5), below.

$$U_r=0.3535\ P(t)rKM_v/(3SH) \quad (5)$$

The acoustic pressure, p(t), is given in equation (6), below, as the result of multiplying equation (5) by the Real part of the specific acoustic impedance, R_e (1).

$$p(t)=R_e\{Z_s U_r\}=R_e(Z_s)U_r \quad (6)$$

The SPL (Sound Pressure Level), in acoustic dB, is approximated as 20 log[p(t)/2E−5]. The standard acoustic reference level of 2E−5 Newtons per square meter is based on a signal in air; however, the head has a water-like consistency. Therefore, the subjective level in acoustic dB is only approximate, but sufficient for first order accuracy.

In a single tone case the incident RF power, P(t), from equation (3) has two terms as shown in equation (7), below, which are in the hearing range.

$$\sin(\omega_a t)-1/4\cos(2\omega_a t) \quad (7)$$

This is converted to the acoustic pressure wave, p(t), by multiplying by the specific acoustic impedance calculated at the two frequencies. Therefore, the resulting pressure wave as indicated in equation (8), below, becomes

$$p(t)=C[Z_s(\omega_a)\sin(\omega_a t)-1/4 Z_s(2\omega_a)\cos(2\omega_3 t)] \quad (8)$$

The result is an audio frequency and a second harmonic at about ¼ amplitude. Thus using an RF carrier, AM modulated by a single tone, the pressure wave audio signal will consist of the audio tone and a second harmonic at about −6 dB, if the specific acoustic impedances at the two frequencies are the same. However, from equation (1) the break frequency of a model 7 cm sphere is 3.547 Hz. Most of the speech spectrum is below this frequency therefore the specific acoustic impedance is reactive and the real component is given by equation (8a), below:

$$R_e\{Z_s(f)\}=\rho_o c(f/f_c)^2/(1+(f/f_c)) \quad (8a)$$

Below the cutoff frequency the real part of the impedance varies as the square of the frequency or gives a boost of 40 dB per decade. Therefore, if the input modulation signal is 1 kHz, the second harmonic will have a boost of about 4 time in amplitude, or 12 dB, due to the variation of the real part of the specific acoustic impedance with frequency. So the second harmonic pressure term in equation (8) is actually four times the power or 6 dB higher than the fundamental term. If the second harmonic falls above the cutoff frequency then the boost begins to fall back to 0 dB. However, for most of the speech spectrum there is a sever distortion and strong boost of the high frequency distortion components.

Results for Two Tone AM Modulation Analysis

Because of the distortion attending single tone modulation, predistortion of the modulation could be attempted such that the resulting demodulated pressure wave will not contain harmonic distortion. This will not work, however, because of the non-linear cross-products of two-tone modulation are quite different from single tone modulation as shown below.

Nevertheless, two-tone modulation distortion provides an insight for the design of a corrective process for a complex modulation signal such as speech. The nature of the distortion is defined in terms of relative amplitudes and frequencies.

Equation (8b) is that of an AM modulated carrier for the two-tone case where ω_{a1} and ω_{a2} are of equal amplitude and together modulate the carrier to a maximum peak value of 100 percent. The total modulated RF signal is given by equation (8b), below:

$$V(t)=A_c\sin(\omega_c t)[1+\tfrac{1}{2}\sin(\omega_{a1}t)+\tfrac{1}{2}\sin(\omega_{a2}t)]$$

The square of (8b) is the power signal, which has the same form as the particle velocity, $U_r(t)$, of equation (9), below.

From the square of (8b) the following frequencies and relative amplitudes are obtained for the particle velocity wave, $U_r(t)$, which are in the audio range;

$$U_r(t)=C[\sin(\omega_{a1}t)+\sin(\omega_{a2}t)+\tfrac{1}{4}\cos((\omega_{a1}-\omega_{a2})(t)=\tfrac{1}{4}\cos((\omega_{a1}+\omega_{a2})t)-\tfrac{1}{8}\cos(2\omega_{a1}t)-\tfrac{1}{8}\cos(2\omega_{a2}t)] \tag{9}$$

If the frequencies in equation (9) are below the cut-off frequency, the impedance boost correction will result in a pressure wave with relative amplitudes given in equation (9a), below:

$$p(t)=C'[\sin(\omega_{a1}t)+b^2\sin(\omega_{a2}t)+(1-b^2)/4\cos((\omega_{a1}-\omega_{a2})t)+(1+b^2)/4\cos((\omega_{a1}+\omega_{a2})t)-\tfrac{1}{2}\cos(2\omega_{a1})t)-b^2/2\cos(2\omega_{a2}t) \tag{9a}$$

where: $b=\omega_{a2}/\omega_{a1}$ and $\omega_{a2}>\omega_{a1}$

Equation (9a) contains a correction factor, b, for the specific acoustic impedance variation with frequency. The first two terms of (9a) are the two tones of the input modulation with the relative amplitudes modified by the impedance correction factor. The other terms are the distortion cross products which are quite different from the single tone distortion case. In addition to the second harmonics, there are sum and difference frequencies. From this two-tone analysis it is obvious that more complex multiple tone modulations, such as speech, will be severely distorted with even more complicated cross-product and sum and difference components. This is not unexpected since the process which creates the distortion is nonlinear. This leads to the conclusion that a simple passive predistortion filter will not work on a speech signal modulated on an RF carrier by a conventional AM process, because the distortion is a function of the signal by a nonlinear process.

However, the serious distortion problem can be overcome by means of the invention which exploits the characteristics of a different type of RF modulation process in addition to special signal processing.

AM Modulation With Fully Suppressed Carrier for the Intelligible Encoding of Speech by the Invention for Compatibility With the RF Hearing Phenomena

The equation for AM modulation with a fully suppressed carrier is given by equation (10), below:

$$V(t)=a(t)\sin(\omega_c t) \tag{10}$$

This modulation is commonly accomplished in hardware by means of a circuit known as a balanced modulator, as disclosed, for example in "Radio Engineering", Frederick E. Terman, p.481–3, McGraw-Hill, 1947.

The power signal has the same form as the particle velocity signal which is obtained from the square of equation (10) as shown in equation (11), below:

$$P(t)=C\ U_r=a(t)^2/2-(a(t)^2/2)\cos(2\omega_\chi t)) \tag{11}$$

From inspection of equations (10) and (11) it is seen that, if the input audio signal, a(t), is pre-processed by taking the square root and then modulating the carrier, the audio term in the particle velocity equation will be an exact, undistorted, replication of the input audio signal. Since the audio signal from a microphone is bipolar, it must be modified by adding a very low frequency (essential d.c.) bias term, A, such that the resultant sum, [a(t)+A]>0.0, is always positive. This is necessary in order to insure a real square root. The use of a custom digital speech processor implements the addition of the term A, i.e. as shown in equation (10*), below:

$$V(t)=(a(t)+A)^{1/2}\sin(\omega_c t) \tag{10*}$$

The pressure wave is given by equation (11*), below:

$$p(t)=C\ U_r=A/2+a(t)/2-(a(t)/2)\cos(2\omega_c t)-(A/2)\cos(2\omega_c t) \tag{11*}$$

When the second term of the pressure wave of equation (11*) is processed through the specific acoustic impedance it will result in the replication of the input audio signal but will be modified by the filter characteristics of the Real part of the specific acoustic impedance, $R_e\{Z_s(f)\}$, as given in equation (8a). The first term of equation (11*) is the d.c. bias, which is added to obtain a real square root; it will not be audible or cause distortion. The third and fourth terms of (11*) are a.c. terms at twice the carrier frequency and therefore will not distort or interfere with the audio range signal, a(t).

Since the filter characteristic of equation (7) is a linear process in amplitude, the audio input can be predistorted before the modulation is applied to the carrier and then the pressure or wound wave audio signal, which is the result of the velocity wave times the impedance function, $R_e\{Z_s(f)\}$, will be the true replication of the original input audio signal.

A diagram illustrating the overall system **30** and process of the invention is shown in FIG. **3**. Then input signal a(t) is applied to an Audio Predistortion Filter **31** with a filter function As(f) to produce a signal a(t)As(f), which is applied to a Square Root Processor **32**, providing an output=$(a(t)As(f)+A)^{1/2}$, which goes to a balanced modulator **33**. The modulation process known as suppressed carrier, produces a double sideband output=$(a(t)As(f)+A)^{1/2}\sin(\omega_c t)$, where ω_c is the carrier frequency. If one of the sidebands and the carrier are suppressed (not shown) the result is single sideband (SSB) modulation and will function in the same manner discussed above for the purposes of implementing the invention. However, the AM double sideband suppressed carrier as described is more easily implemented.

The output of the balanced modulator is applied to a spherical demodulator **34**, which recovers the input signal a(t) that is applied to the inner ear **35** and then to the acoustic receptors in the brain **36**.

The various components **31**–**33** of FIG. **3** are easily implemented as shown, for example by the corresponding components **41**–**42** in FIG. **4**, where the Filter **41** can take the form of a low pass filter, such as a constant-K filter formed by series inductor L and a shunt capacitor C. Other low-pass filters are shown, for example, in the ITT Federal Handbook, 4th Ed., 1949. As a result the filter output is AS(f) a $1/f^2$. The Root Processor **42** can be implemented by any square-law device, such as the diode D biased by a battery B and in series with a large impedance (resistance) R, so that the voltage developed across the diode D is proportional to the square root of the input voltage a(t)As(f). The balanced modulator **43**, as discussed in Terman, op.cit., has symmetrical diodes **A1** and **A2** with the modulating voltage M applied in opposite phase to the diodes **A1** and **A2** through an input transformer **T1**, with the carrier, O, applied commonly to the diodes in the same phase, while the modulating signal is applied to the diodes in opposite phase so that the carrier cancels in the primary of the output transformer **T2** and the secondary output is the desired double side band output.

Finally the Spherical Demodulator **45** is the brain as discussed above, or an equivalent mass that provides uniform expansion and contraction due to thermal effects of RF energy.

The invention provides a new and useful encoding for speech on an RF carrier such that the speech will be intelligible to a human subject by means of the RF hearing demodulation phenomena. Features of the invention include the use of AM fully suppressed carrier modulation, the preprocessing of an input speech signal be a compensation filter to de-emphasize the high frequency content by 40 dB per decade and the further processing of the audio signal by adding a bias terms to permit the taking of the square root of the signal before the AM suppressed carrier modulation process.

The invention may also be implemented using the same audio signal processing and Single Sideband (SSB) modulation in place of AM suppressed carrier modulation. The same signal processing may also be used on Conventional AM modulation contains both sideband and the carrier; however, there is a serious disadvantage. The carrier is always present with AM modulation, even when there is no signal. The carrier power does not contain any information but contributes substantially to the heating of the thermal-acoustic demodulator, i.e. the brain, which is undesirable. The degree of this extraneous heating is more than twice the heating caused by the signal or information power in the RF signal. Therefore conventional AM modulation is an inefficient and poor choice compared to the double side-band suppressed carrier and the SSB types of transmissions.

The invention further may be implemented using various degrees of speech compression commonly used with all types of AM modulation. Speech compression is implemented by raising the level of the low amplitude portions of the speech waveform and limiting or compressing the high peak amplitudes of the speech waveform. Speech compression increases the average power content of the waveform and thus loudness. Speech compression introduces some distortion, so that a balance must be made between the increase in distortion and the increase in loudness to obtain the optimum result.

Another implementation is by digital signal processing of the input signal through to the modulation of the RF carrier.

What is claimed is:

1. An apparatus for communicating an audio signal a(t), comprising:

an audio predistortion filter having a filter function As(f) for producing a first output signal a(t)As(t) from the audio signal a(t);

means for adding a bias A to the first output signal, to produce a second output signal a(t)As(f)+A;

a square root processor for producing a third output signal $(a(t)As(f)+A)^{1/2}$ responsive to the second output signal; and

a modulator for producing a double sideband output signal responsive to the third output signal, having a carrier frequency of ω_c, and being mathematically described by $(a(t)As(f)+A)^{1/2}\sin(\omega_c t)$; and

transmitting the double sideband output signal to a demodulator, whereby the audio signal a(t) is recovered from the double sideband output signal.

2. The communication apparatus defined in claim **1** wherein:

the double sideband output signal has RF power; and

the demodulator is for converting the RF power into acoustic pressure waves.

3. The communication apparatus defined in claim **2** wherein:

the demodulator converts the RF power into the acoustic pressure waves by means of thermal expansion and contraction, whereby

the acoustic pressure waves approximate the audio signal a(t).

4. The communication apparatus defined in claim **2** wherein the demodulator includes a mass that expands and contracts responsive to the RE power of the double sideband output signal.

5. The communication apparatus defined in claim **4** wherein the mass is approximately spherical.

6. The communication apparatus defined in claim **1** wherein:

the double sideband output signal is comprised of a first sideband component and a second sideband component; and

means for suppressing the second sideband component, whereby

the demodulator recovers the audio signal a(t) solely from the first sideband component.

7. The communication apparatus defined in claim **1** wherein the audio predistortion filter is a low-pass filter.

8. The communication apparatus defined in claim **7** wherein the audio predistortion filter is a digital processor.

9. The communication apparatus defined in claim **1** wherein:

the square root processor is a diode biased by a voltage source, in series with a resistance, whereby

a voltage across the diode is proportional to a square root of the second output signal a(t)As(t)+A.

10. The communication apparatus defined in claim **1** wherein the modulator is a balanced modulator.

11. The communication apparatus defined in claim **1** wherein:

the audio signal a(t) includes a high frequency component; and

the audio predistortion filter de-emphasizes the high frequency component by approximately 40 dB per decade.

* * * * *

US007609001B2

(12) **United States Patent**
Small

(10) **Patent No.: US 7,609,001 B2**
(45) **Date of Patent: *Oct. 27, 2009**

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(54) **OPTICAL MAGNETRON FOR HIGH EFFICIENCY PRODUCTION OF OPTICAL RADIATION AND RELATED METHODS OF USE**

(75) Inventor: **James G. Small**, Tucson, AZ (US)

(73) Assignee: **Raytheon Company**, Waltham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 288 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/567,388**

(22) Filed: **Dec. 6, 2006**

(65) **Prior Publication Data**

US 2008/0296508 A1 Dec. 4, 2008

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/982,591, filed on Nov. 5, 2004, now Pat. No. 7,265,360.

(51) **Int. Cl.**
H01J 25/50 (2006.01)

(52) **U.S. Cl.** **315/39.51**; 315/39.53; 315/39.65; 315/39.75

(58) **Field of Classification Search** 315/39.51, 315/39.65, 39.73, 39.75, 39.77, 39.53
See application file for complete search history.

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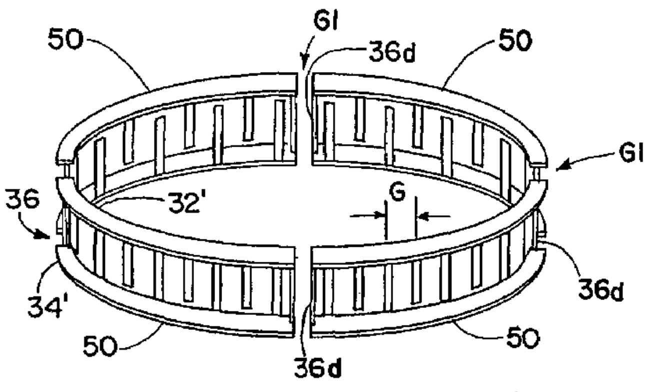
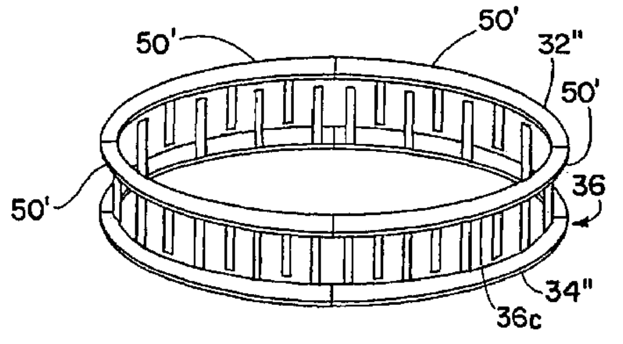
Primary Examiner—Douglas W. Owens
Assistant Examiner—Chuc Tran
(74) *Attorney, Agent, or Firm*—Renner, Otto, Boisselle & Sklar, LLP

(57) **ABSTRACT**

An electromagnetic radiation source is disclosed that produces a single mode operation at a desired operating frequency. The electromagnetic radiation source is included in a wide variety of applications including a wireless power transmission system, a system for providing wireless/high-bandwidth communications in accordance with the present invention, a lighting system, an irradiation system, a weapons system, etc.

20 Claims, 14 Drawing Sheets





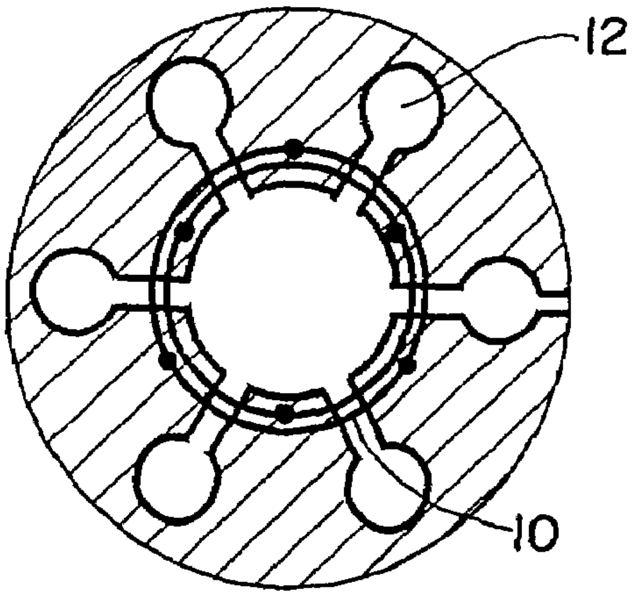


FIG. 1A

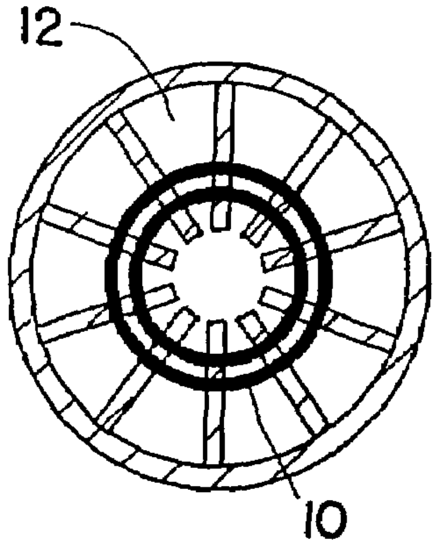


FIG. 1B

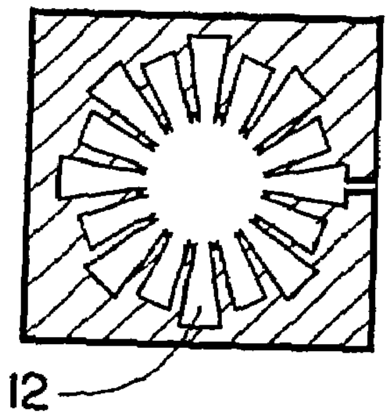


FIG. 1C

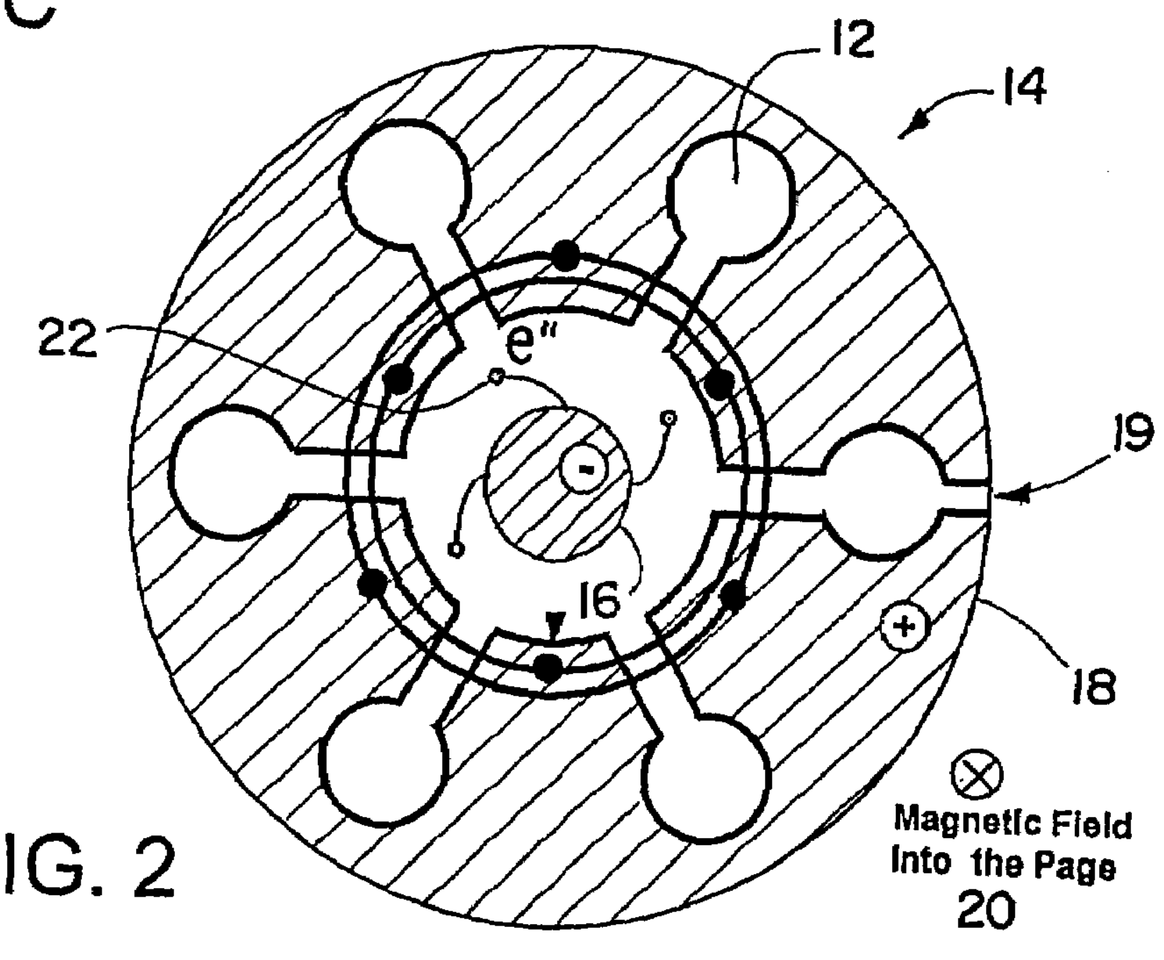


FIG. 2

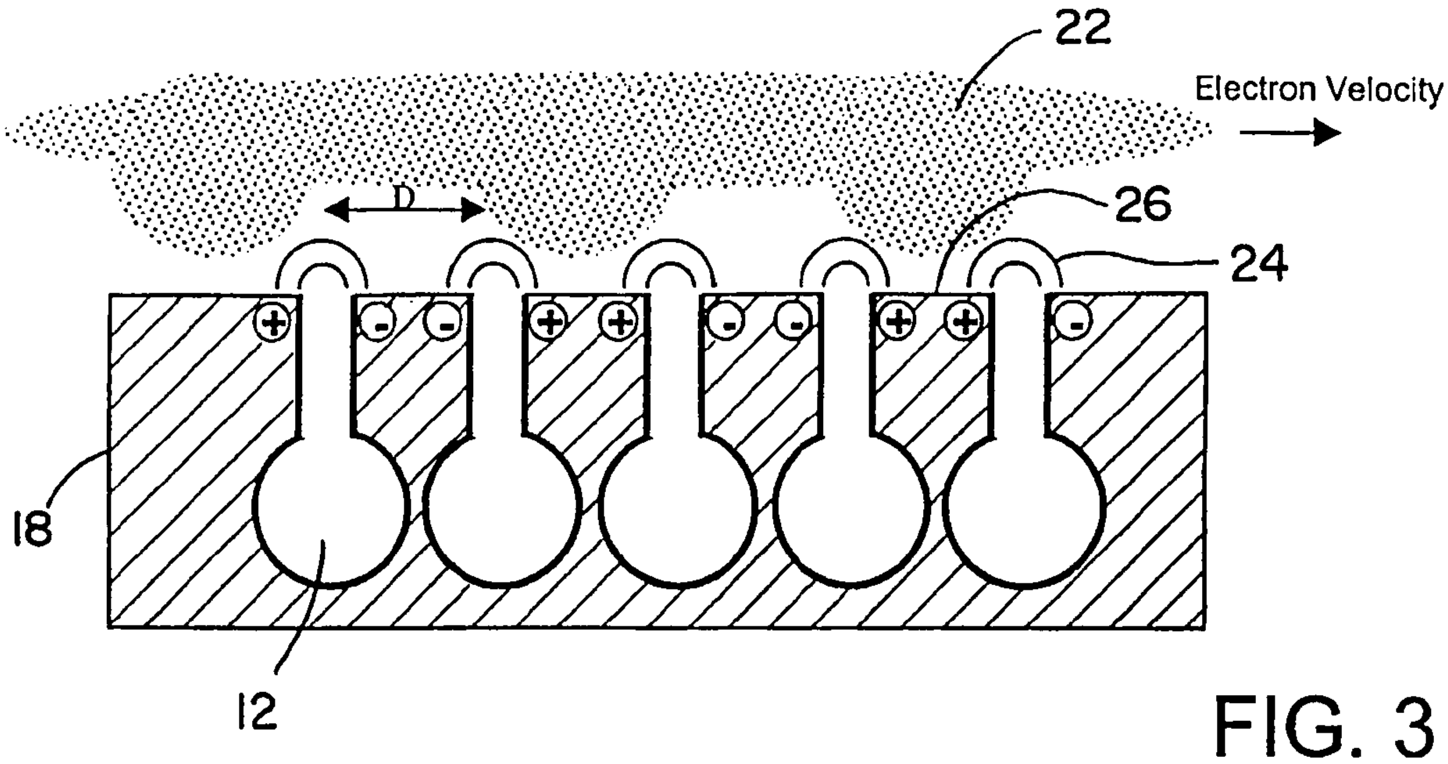


FIG. 3

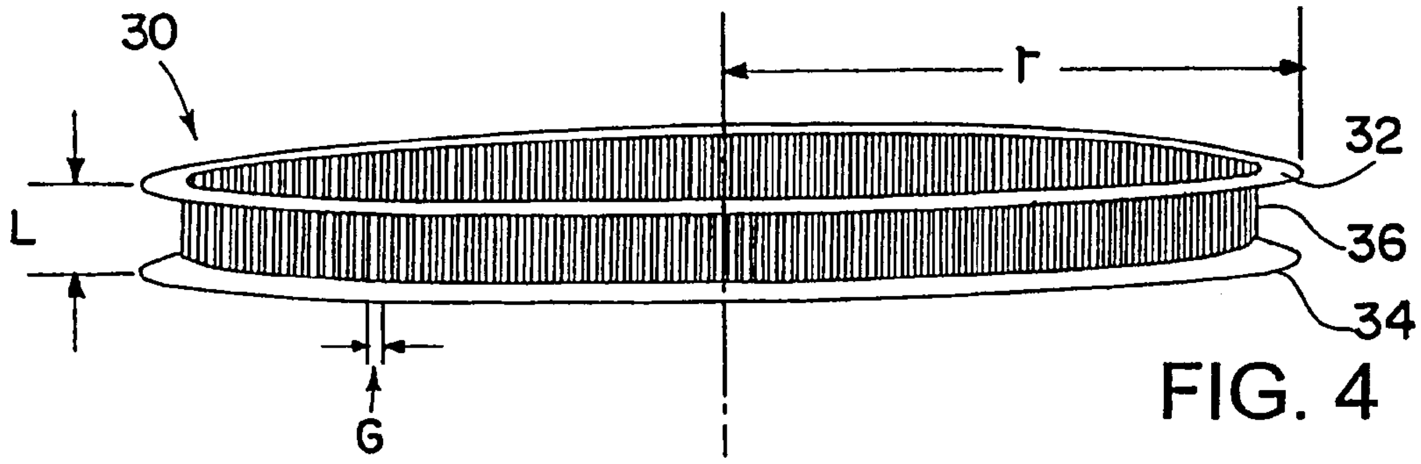


FIG. 4

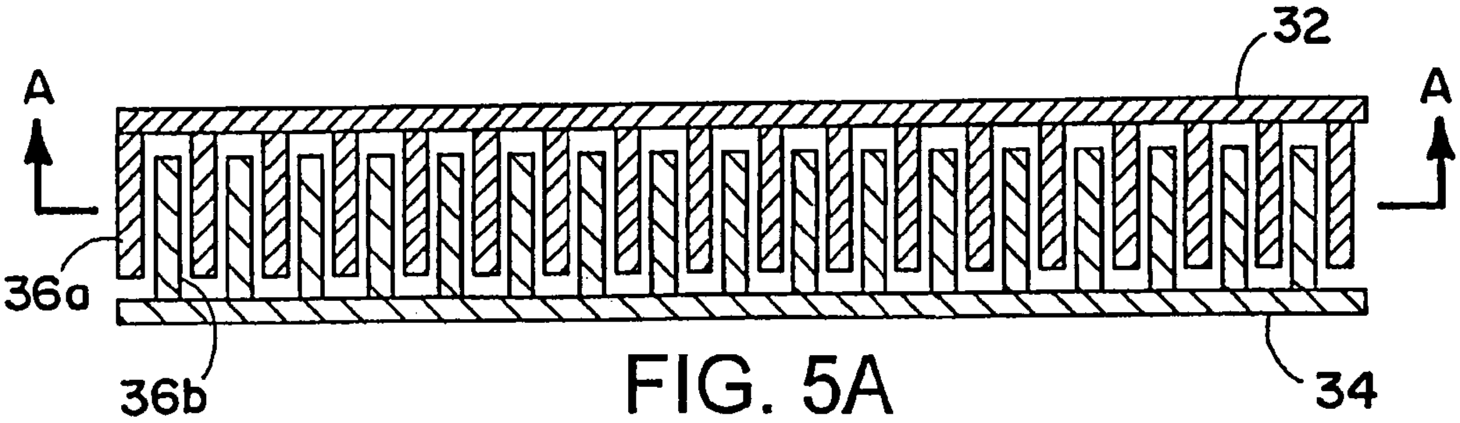


FIG. 5A

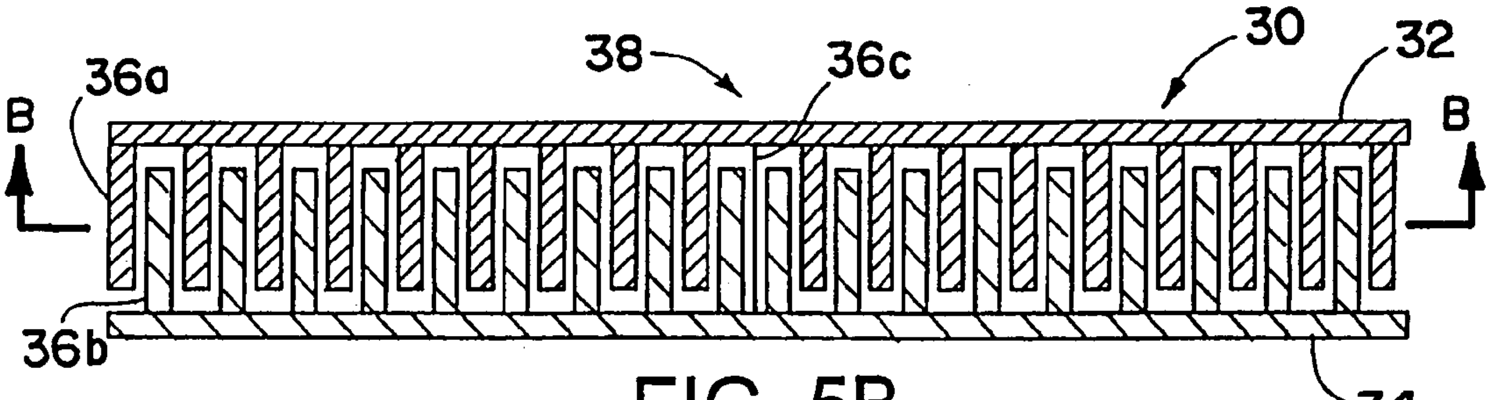


FIG. 5B

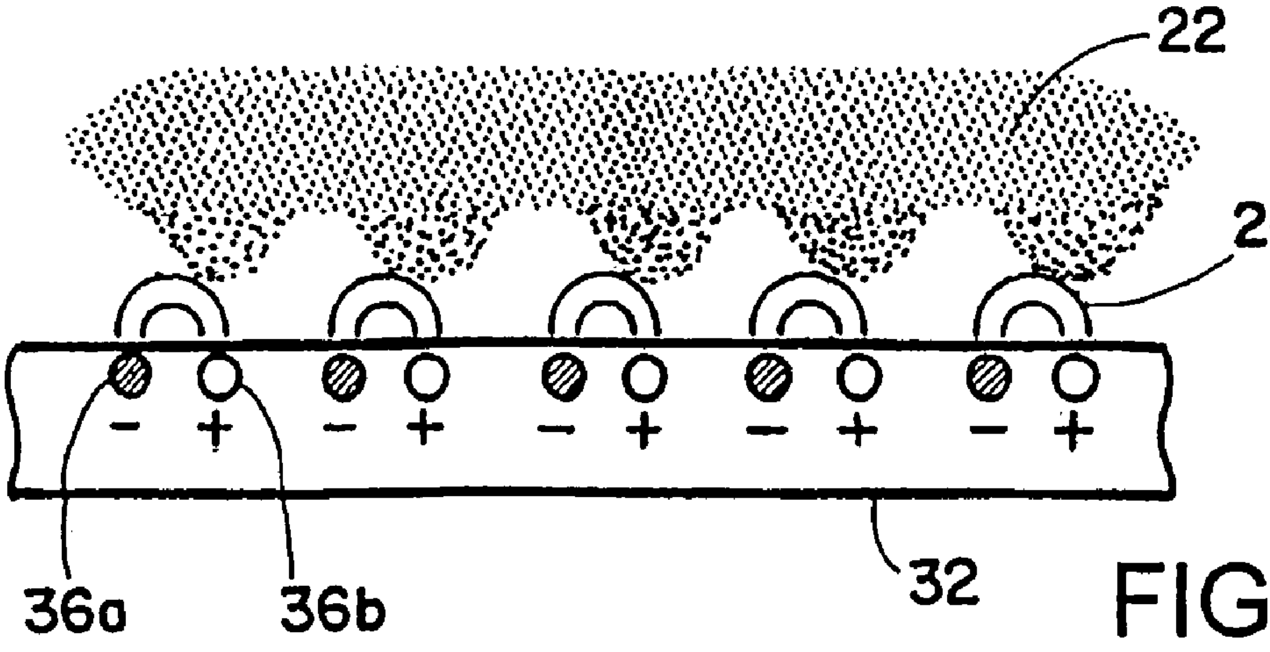

22
24
−
+
36a
36b
32

FIG. 6A

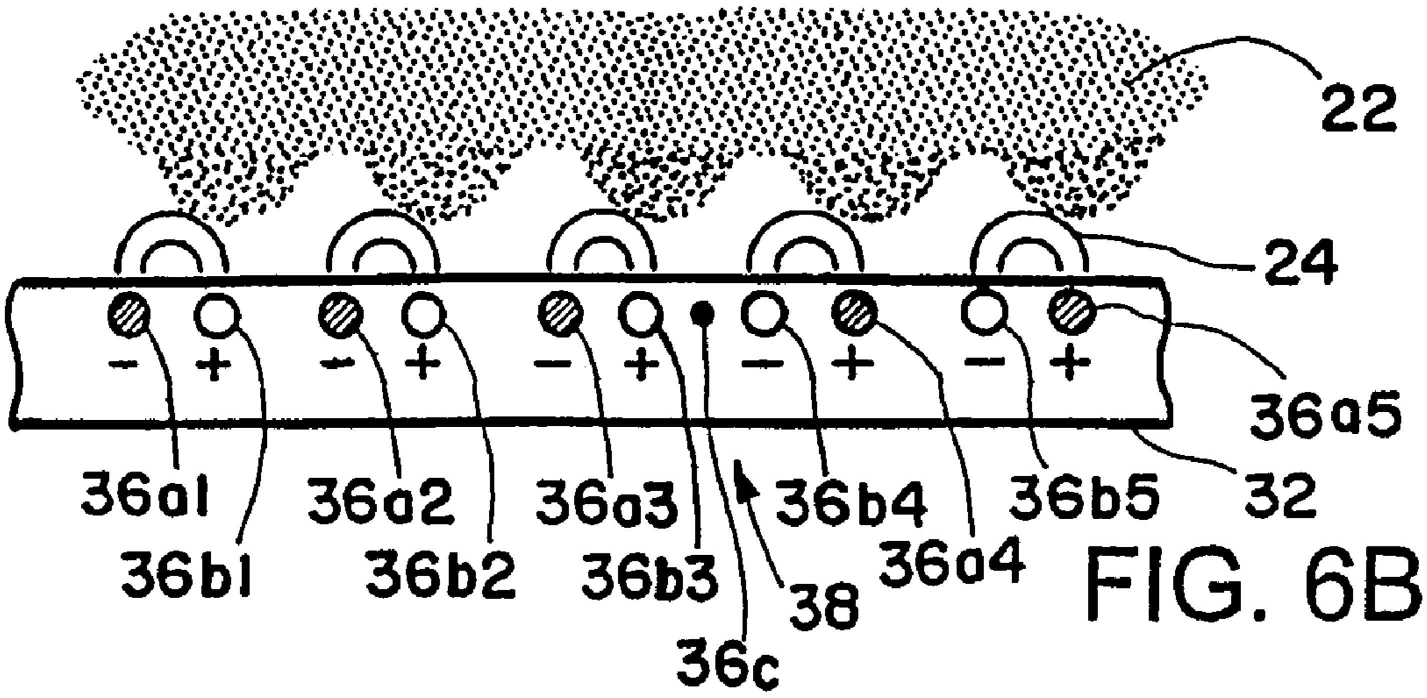
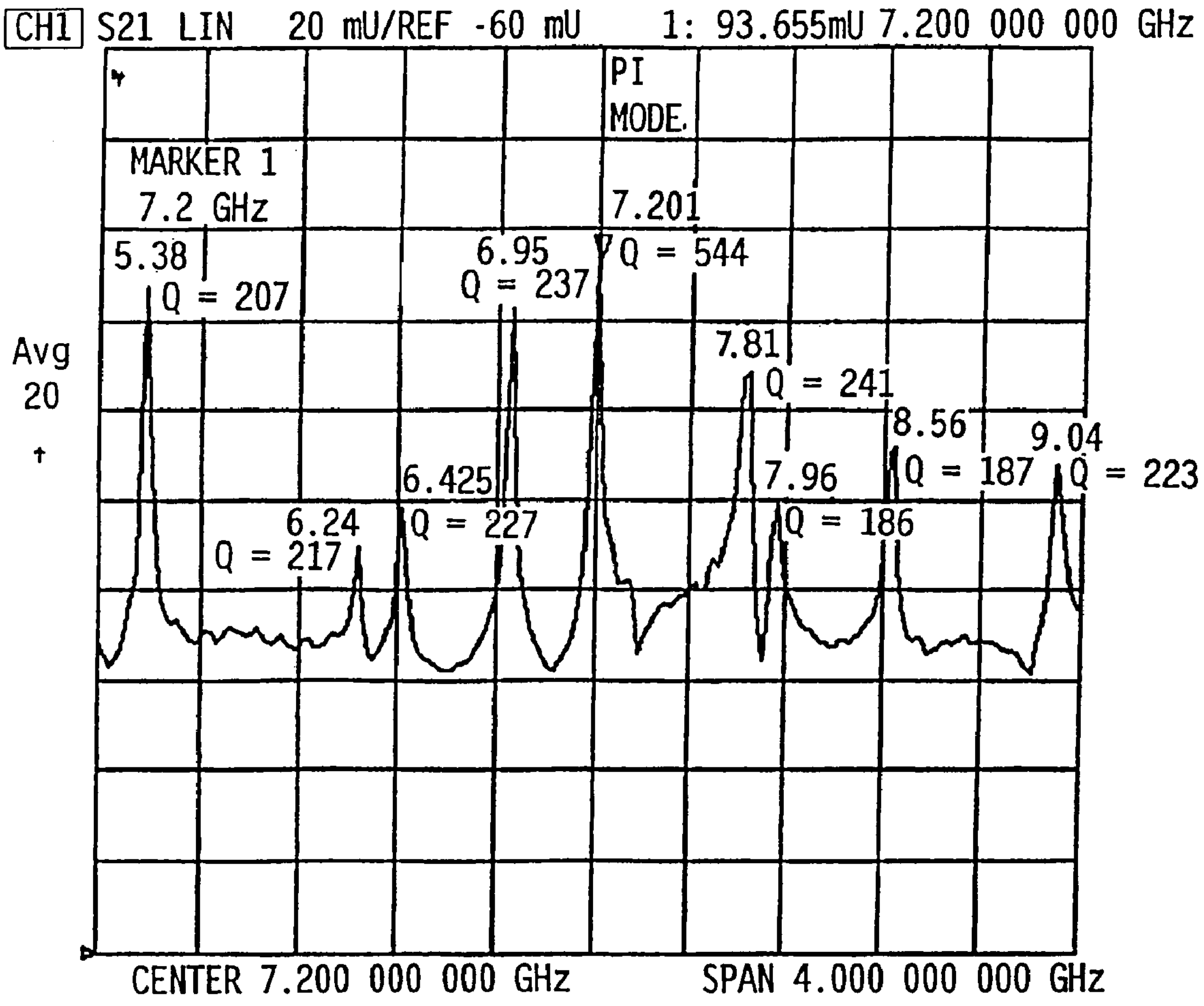

22
24
−
+
36a5
32
36a1
36b1
36a2
36b2
36a3
36b3
38
36c
36b4
36a4
36b5

FIG. 6B



SMALL DIAMETER

PI MODE = 7.201 GHz

Q = 544

FIG. 7A

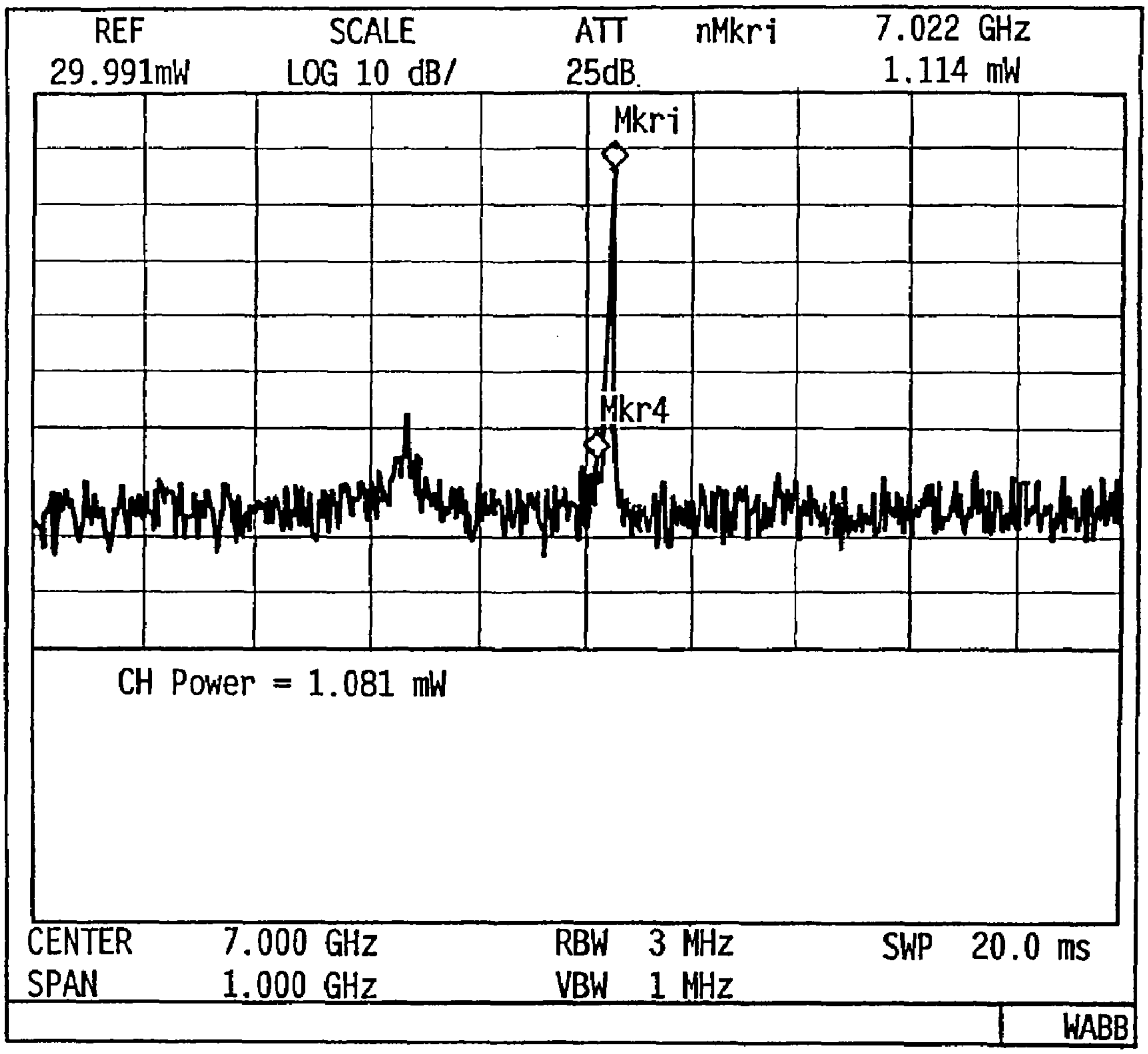

REF
29.991mW
SCALE
LOG 10 dB/
ATT
25dB
nMkri
7.022 GHz
1.114 mW
Mkri
Mkr4
CH Power = 1.081 mW
CENTER 7.000 GHz
SPAN 1.000 GHz
RBW 3 MHz
VBW 1 MHz
SWP 20.0 ms
WABB

FIG. 7B

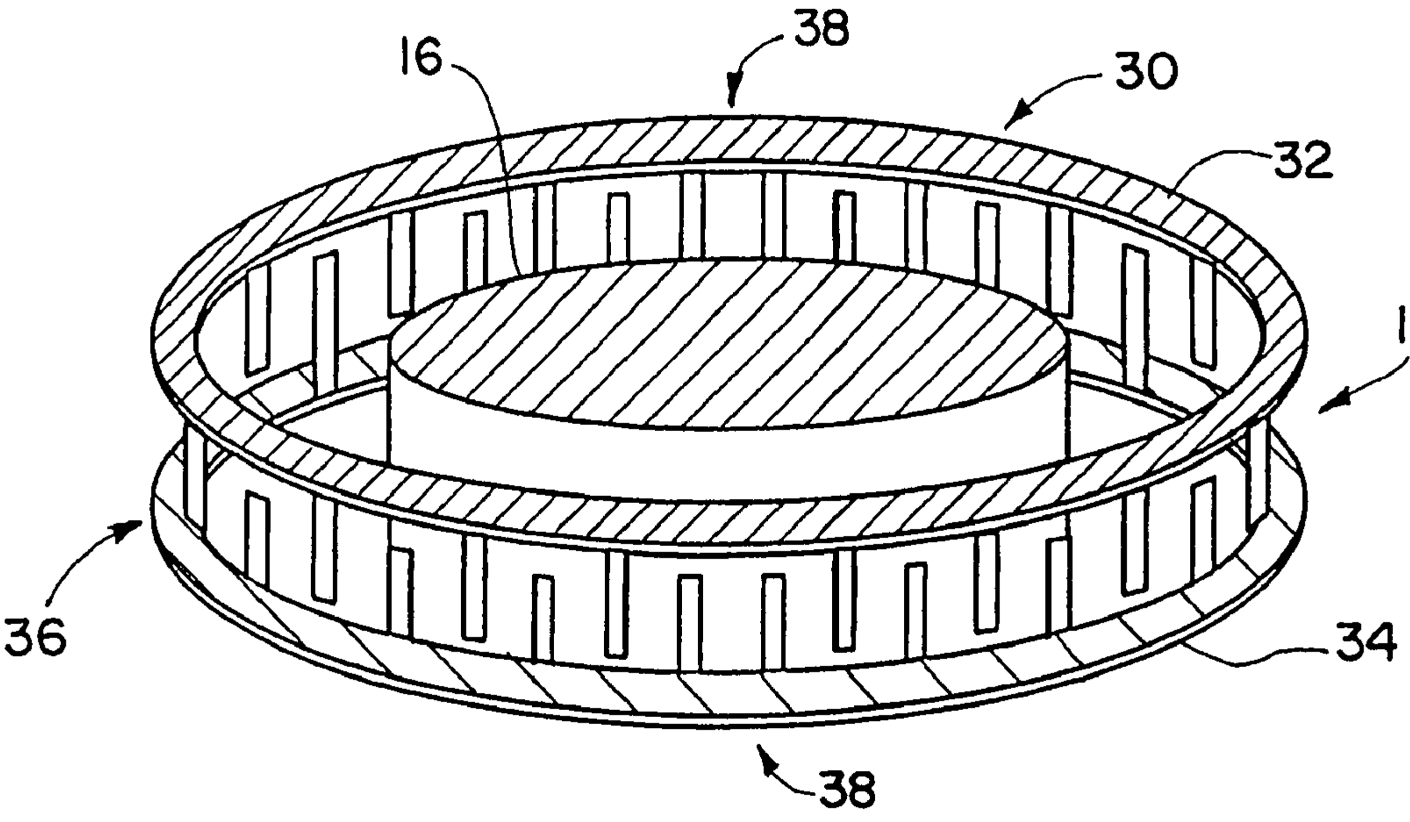

38
16
30
32
14'
36
34
38

FIG. 8A

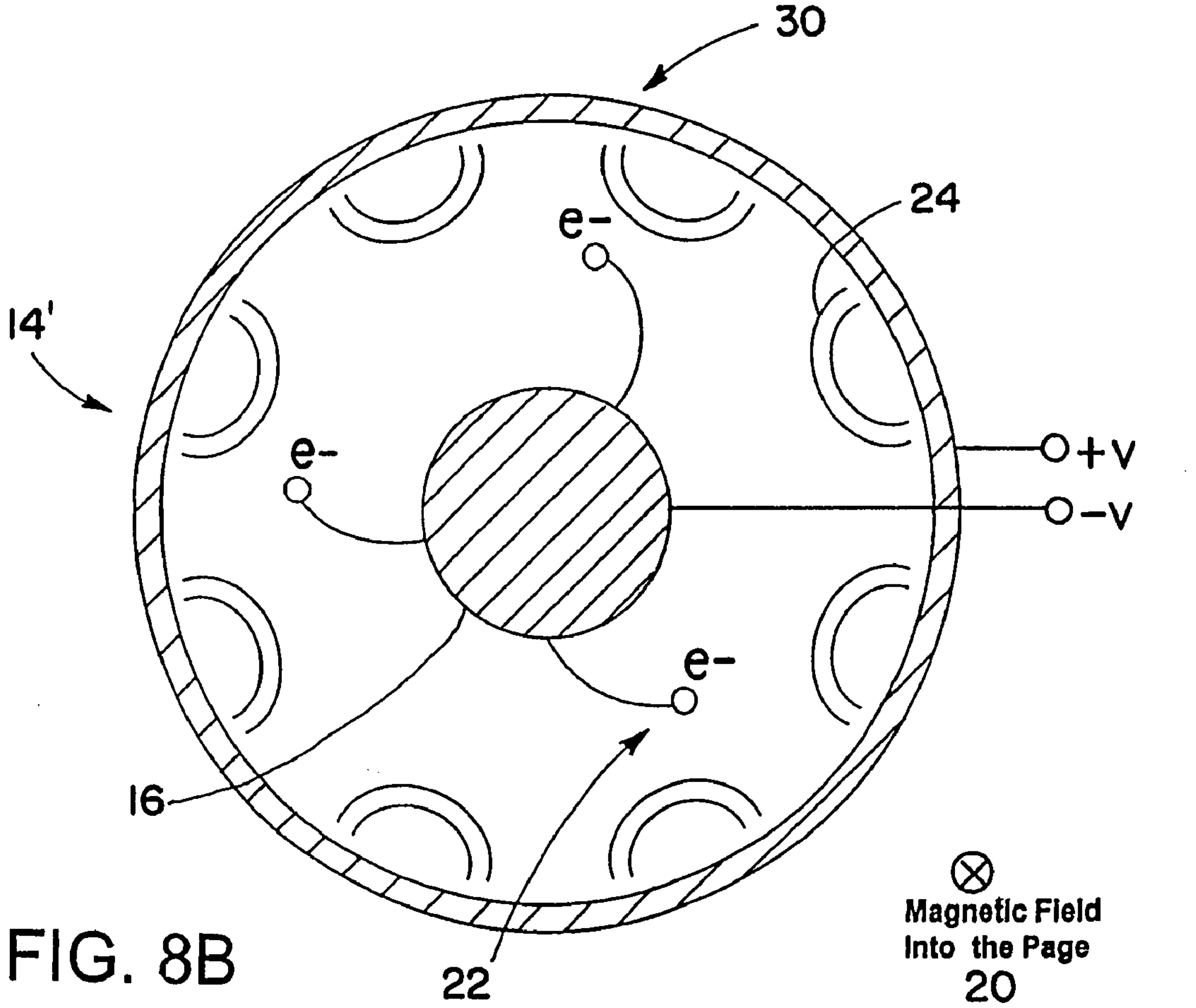

30
24
e-
14'
e-
+V
-V
e-
16
22
⊗
Magnetic Field
Into the Page
20

FIG. 8B

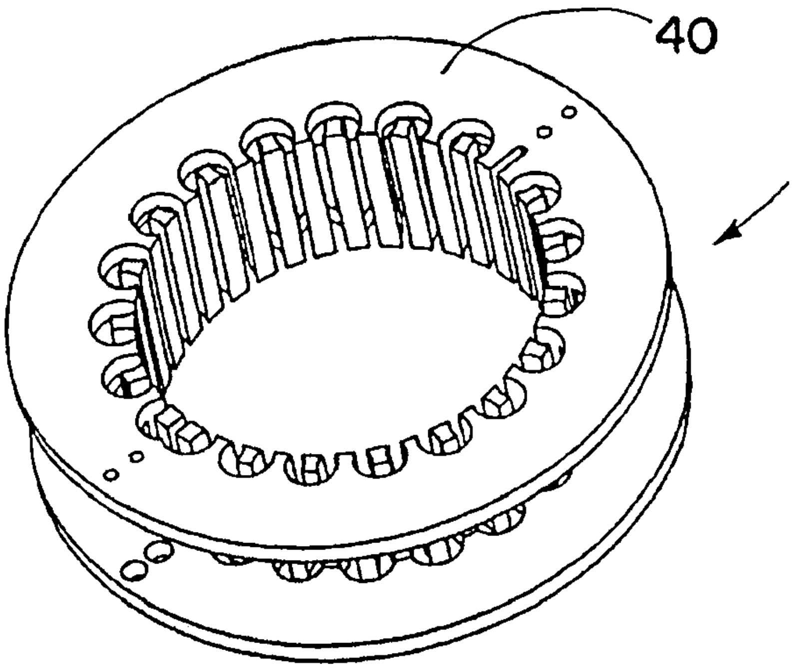


FIG. 9

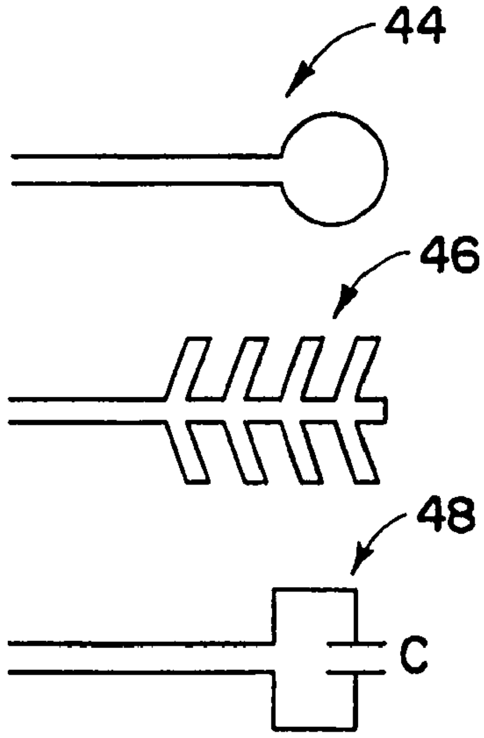


FIG. 12

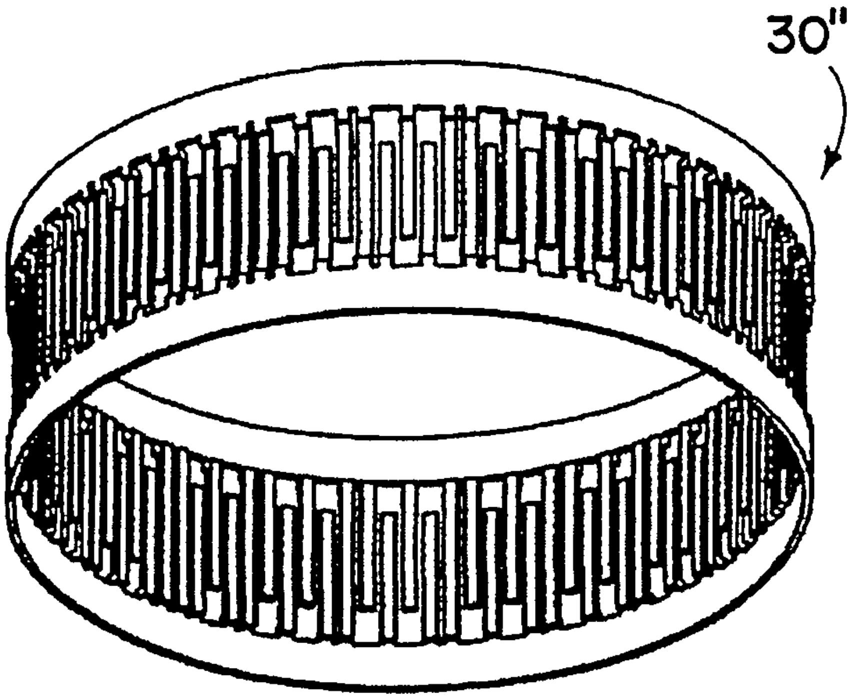


FIG. 10

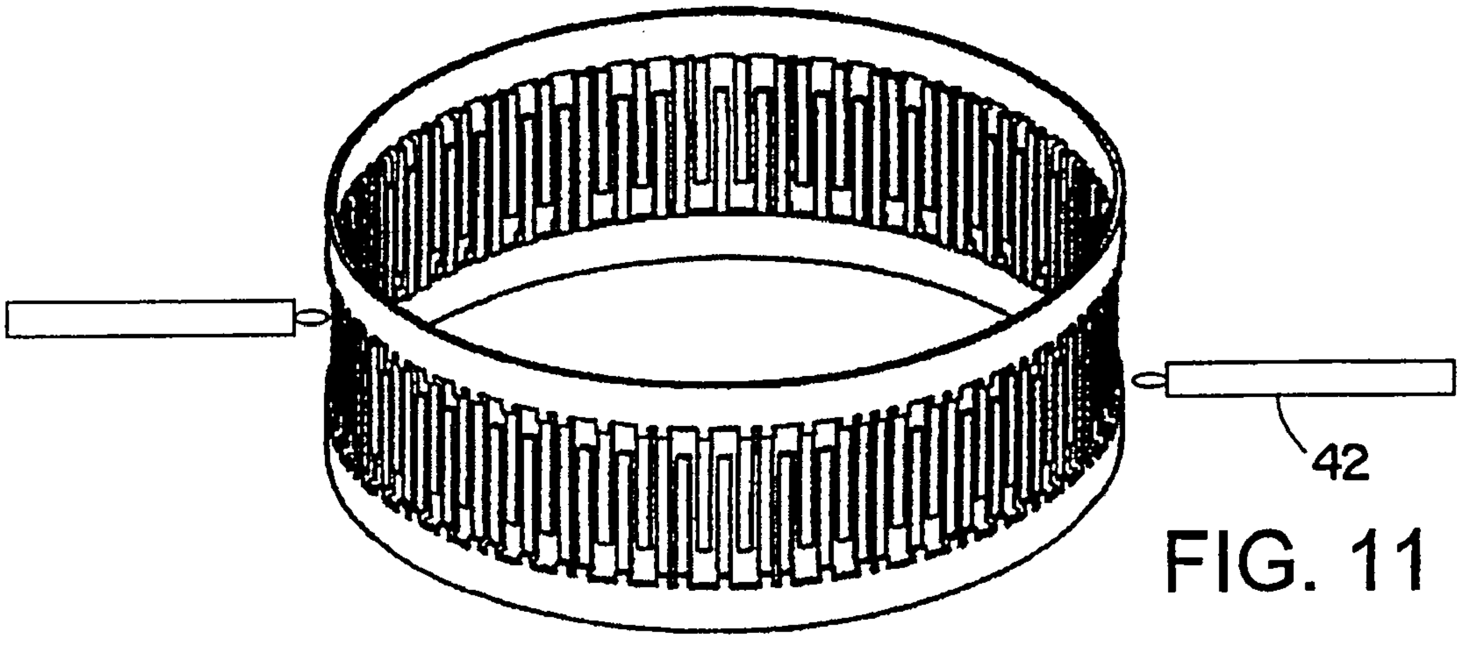


FIG. 11

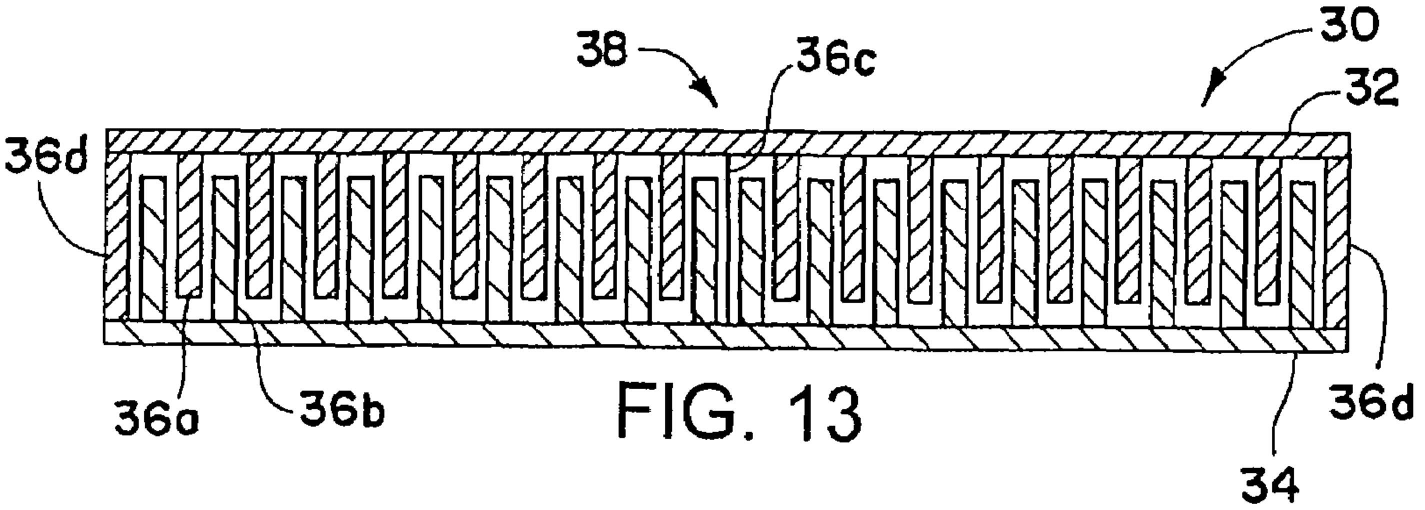


FIG. 13

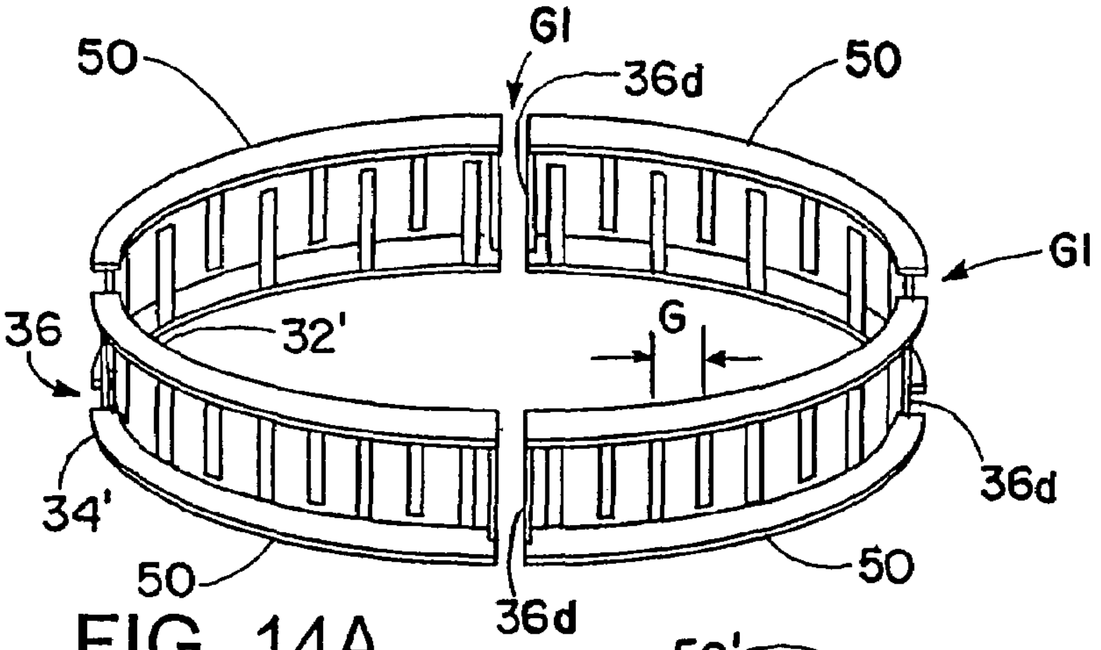


FIG. 14A

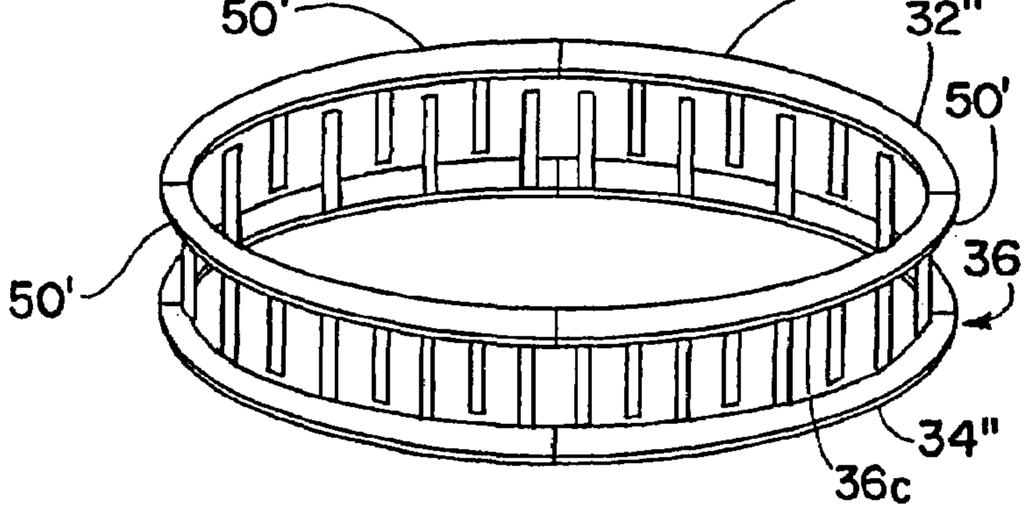


FIG. 14B

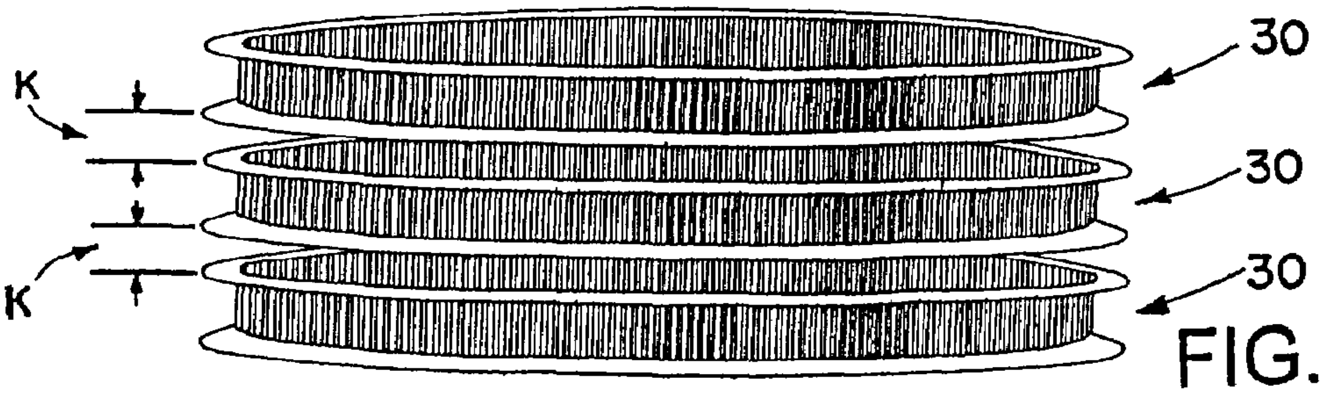


FIG. 15

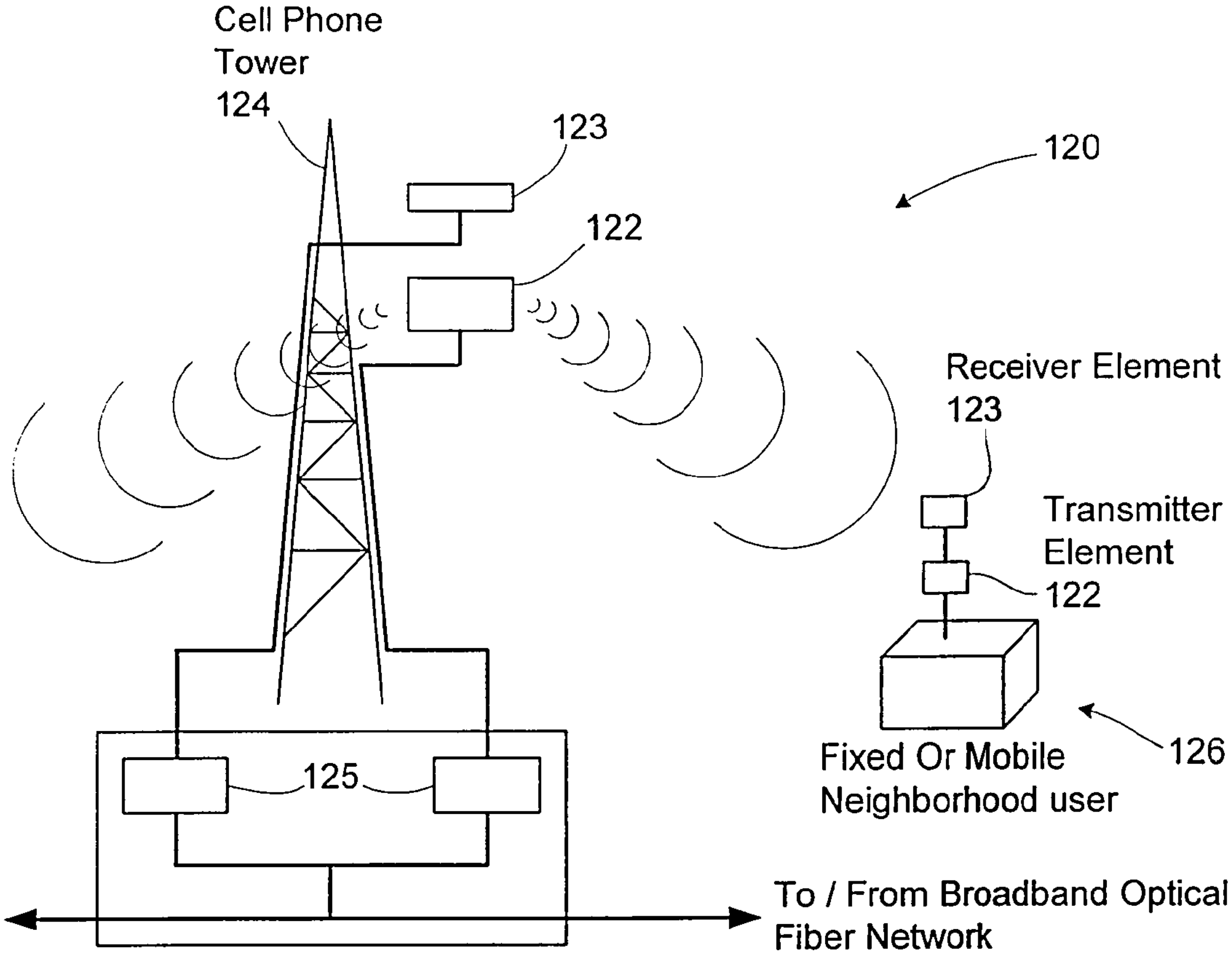
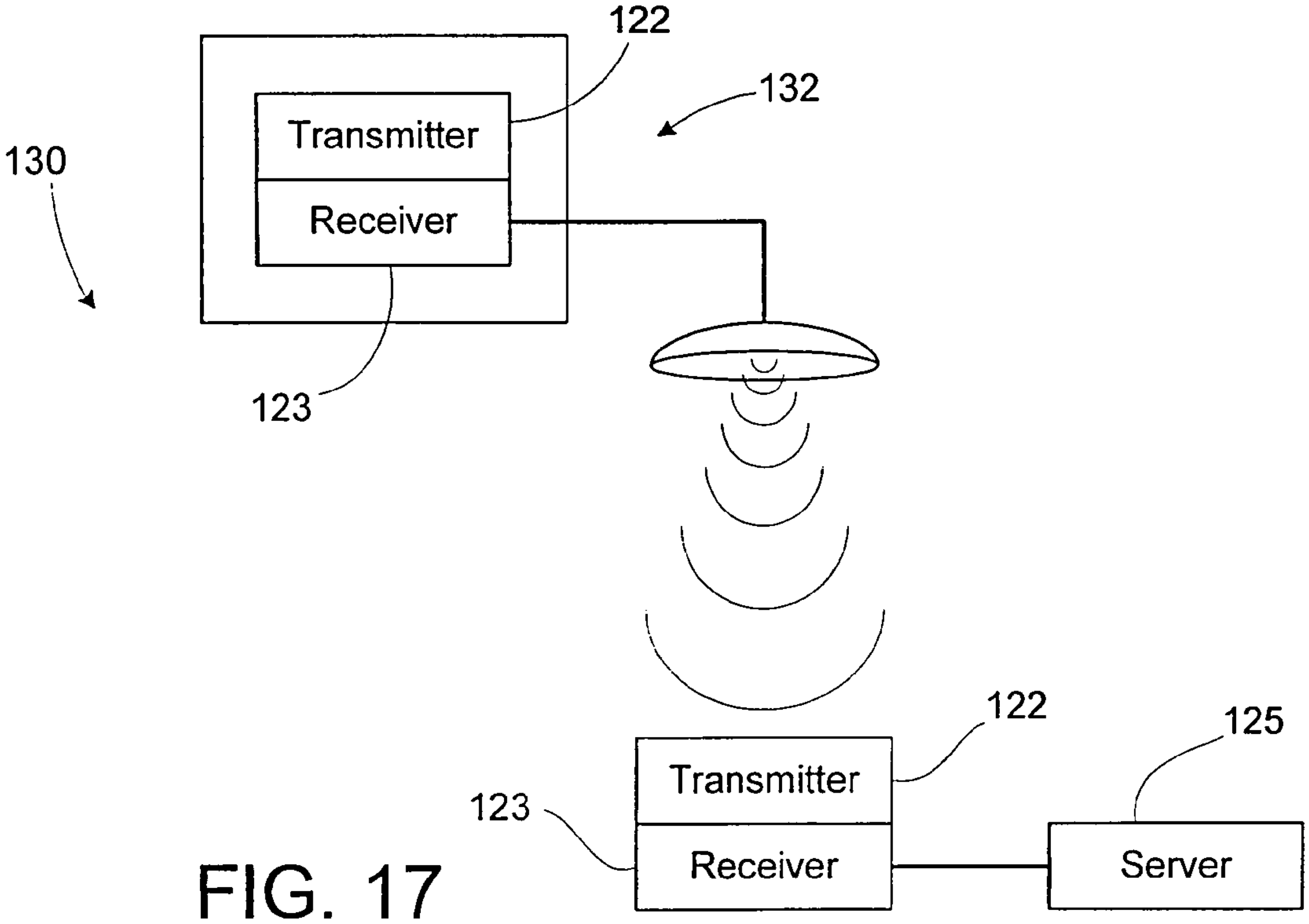

Cell Phone
Tower
124
123
120
122
Receiver Element
123
Transmitter
Element
122
125
Fixed Or Mobile
Neighborhood user
126
To / From Broadband Optical
Fiber Network

FIG. 16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132
130
Transmitter
Receiver
123
122
125
123
Transmitter
Receiver
Server

FIG. 17

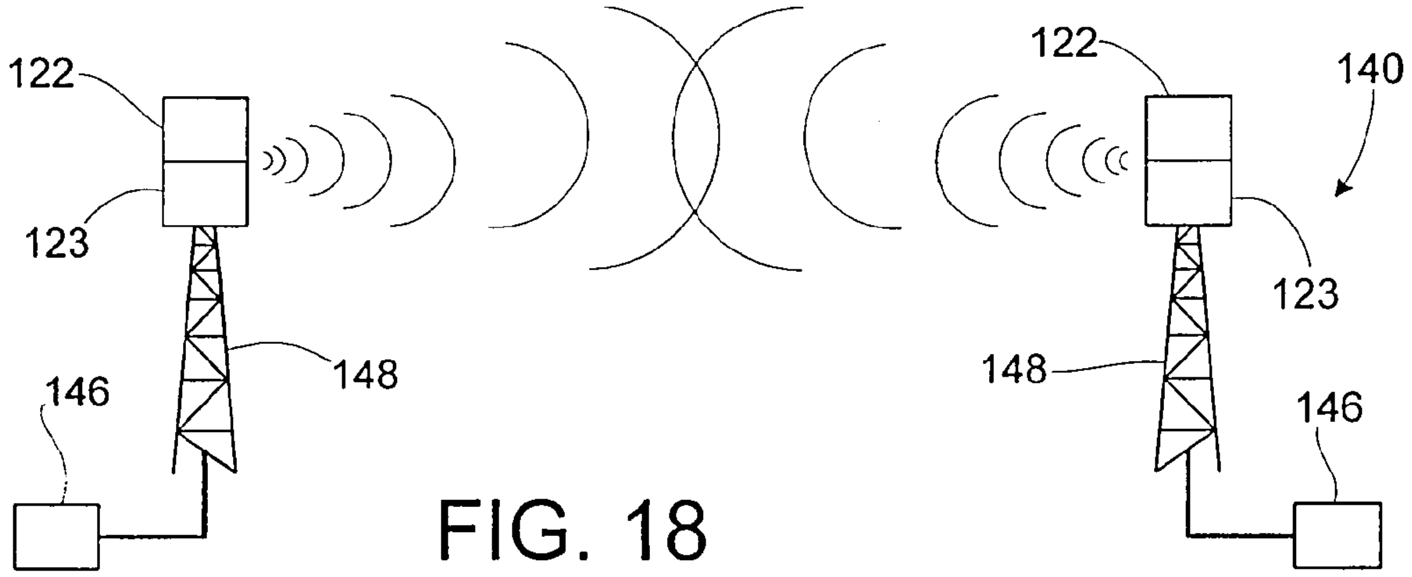


FIG. 18

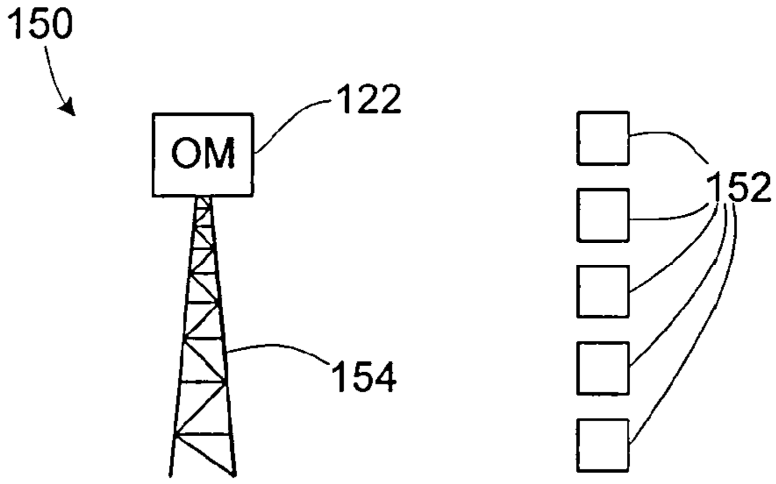


FIG. 19

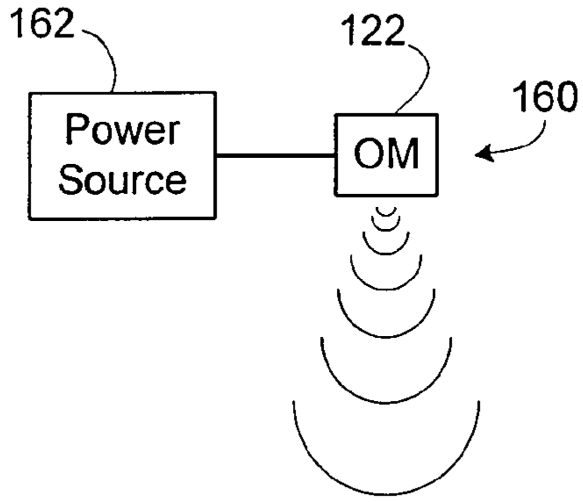


FIG. 20

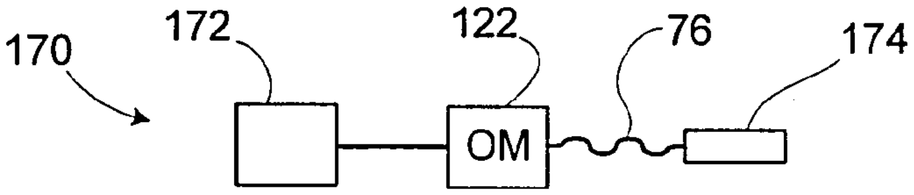


FIG. 21

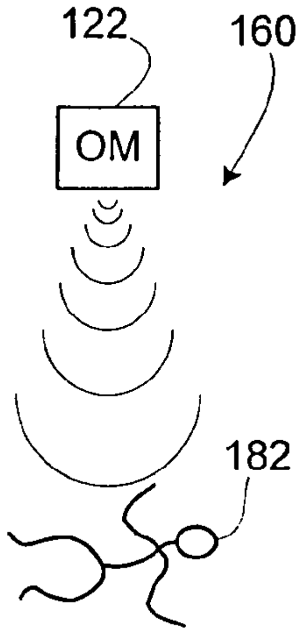


FIG. 22

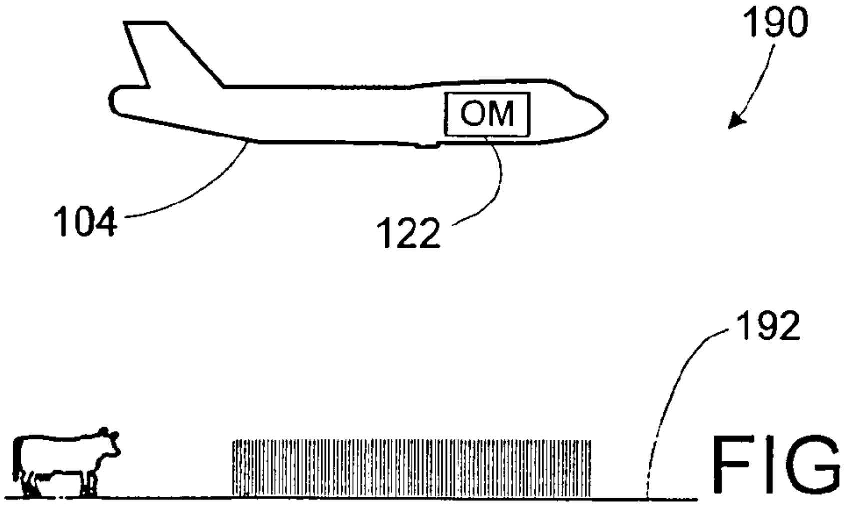


FIG. 23

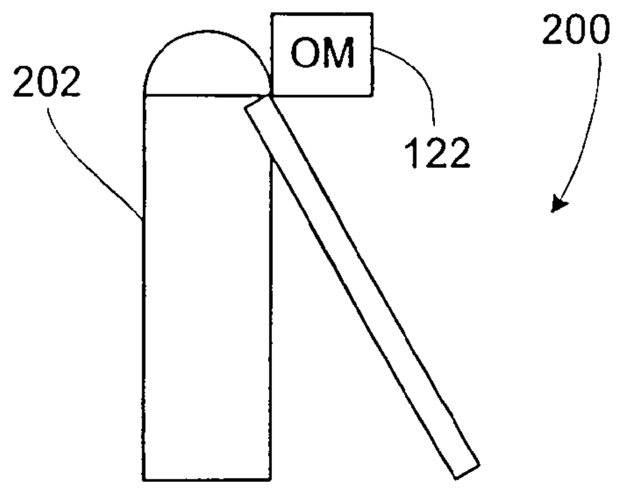


FIG. 24

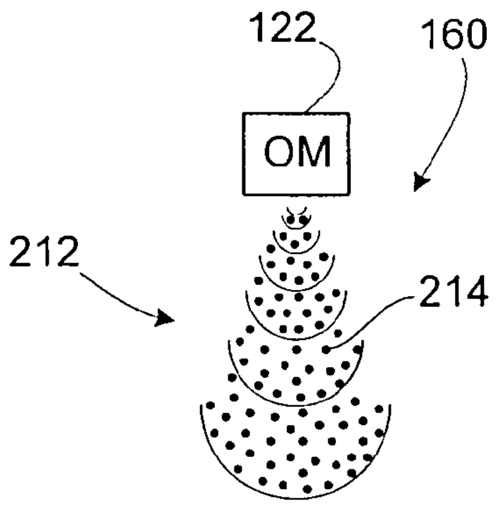


FIG. 25

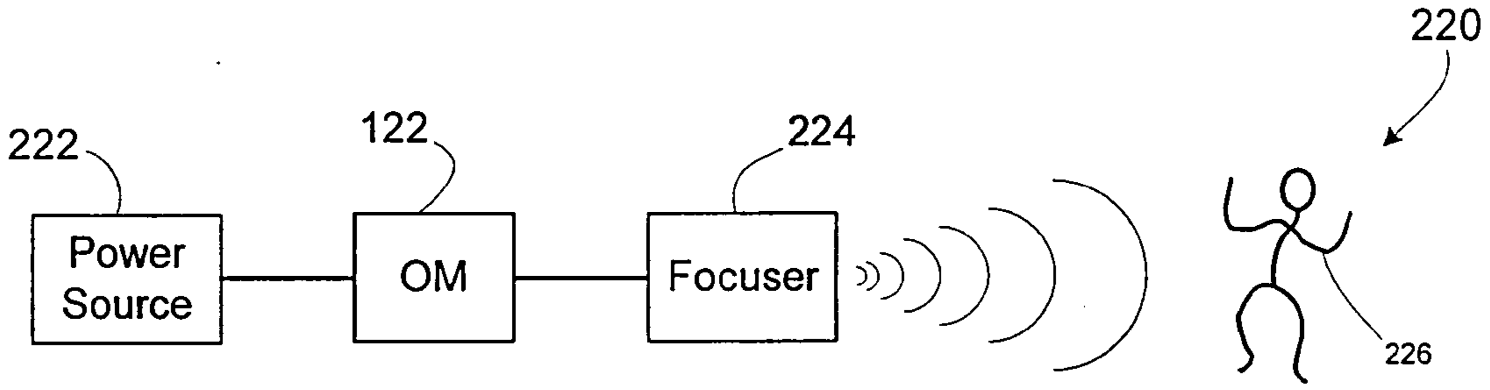


FIG. 26

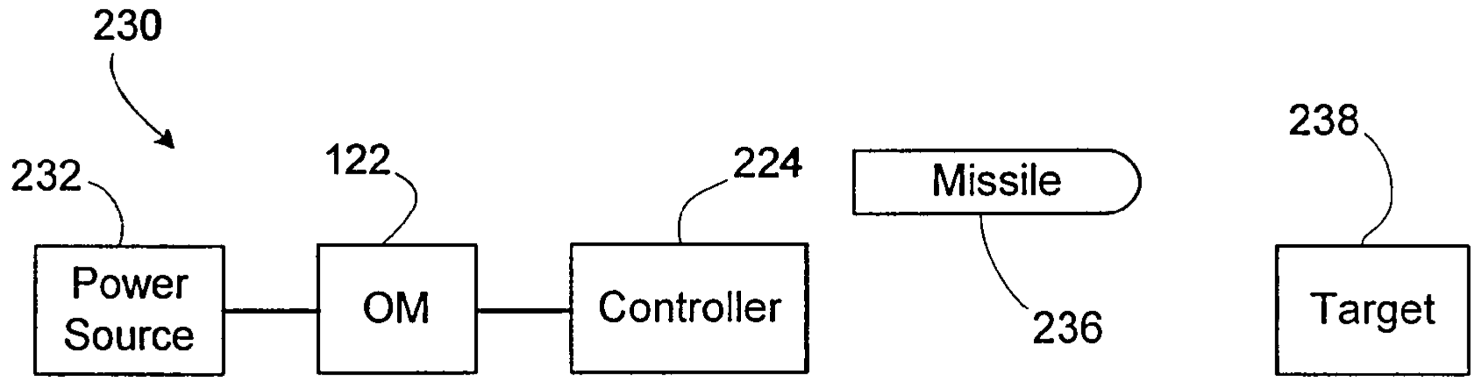


FIG. 27

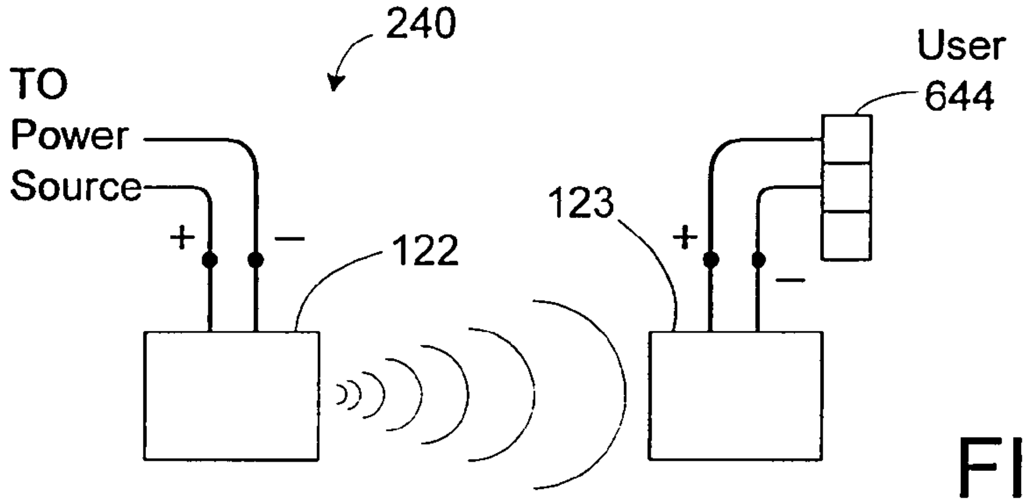


FIG. 28

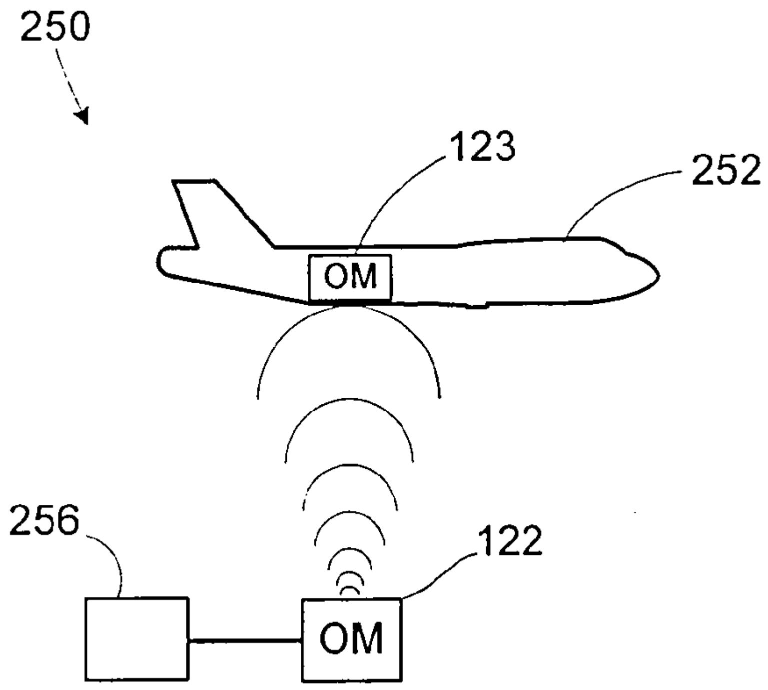


FIG. 29

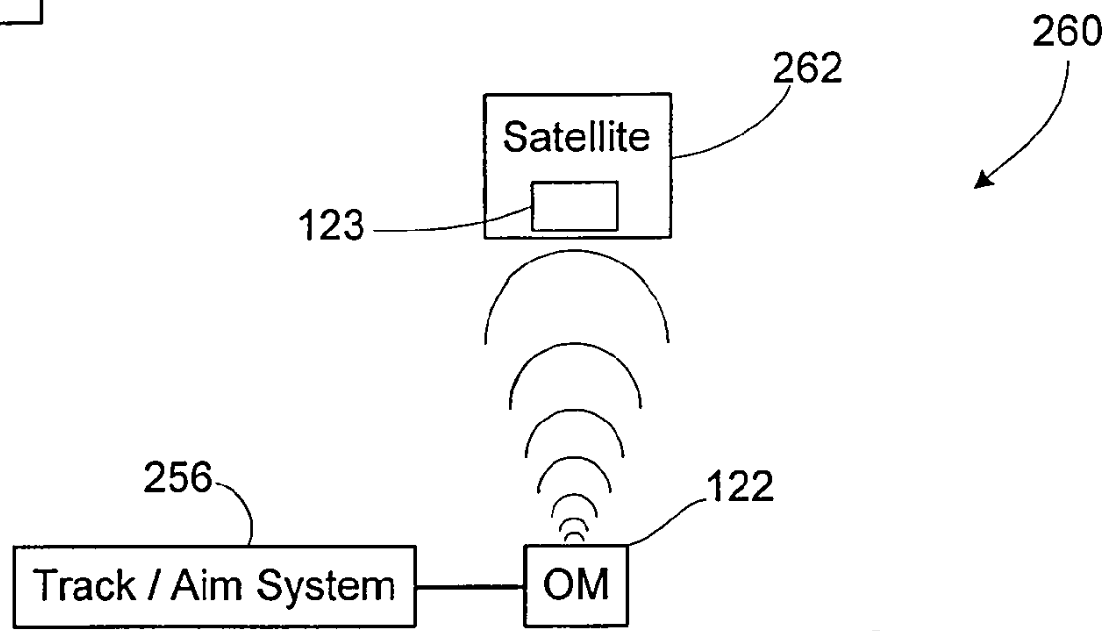


FIG. 30

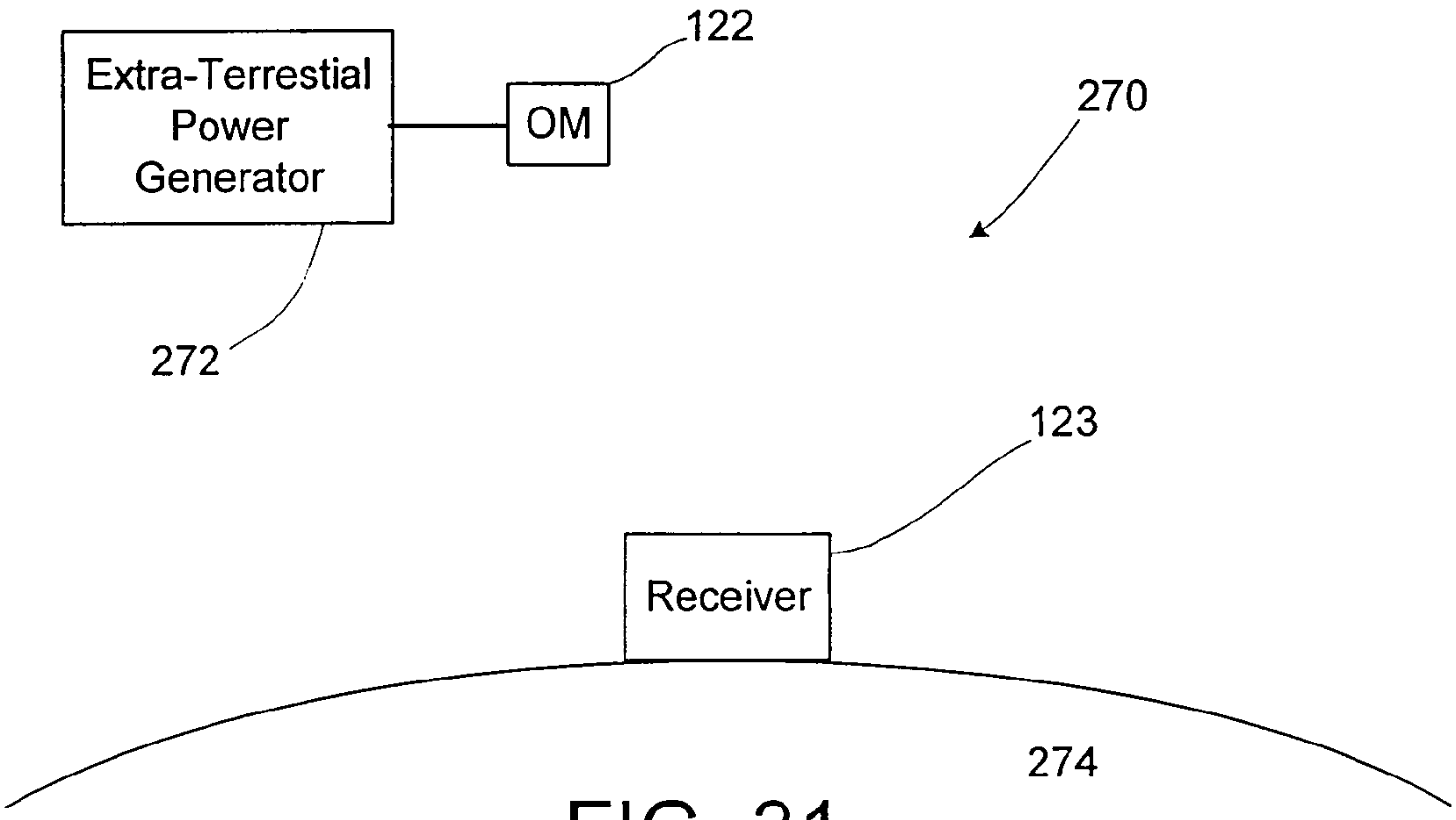


FIG. 31

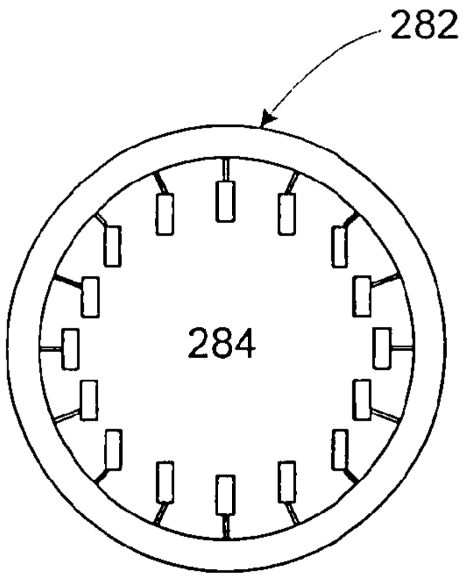


FIG. 32A

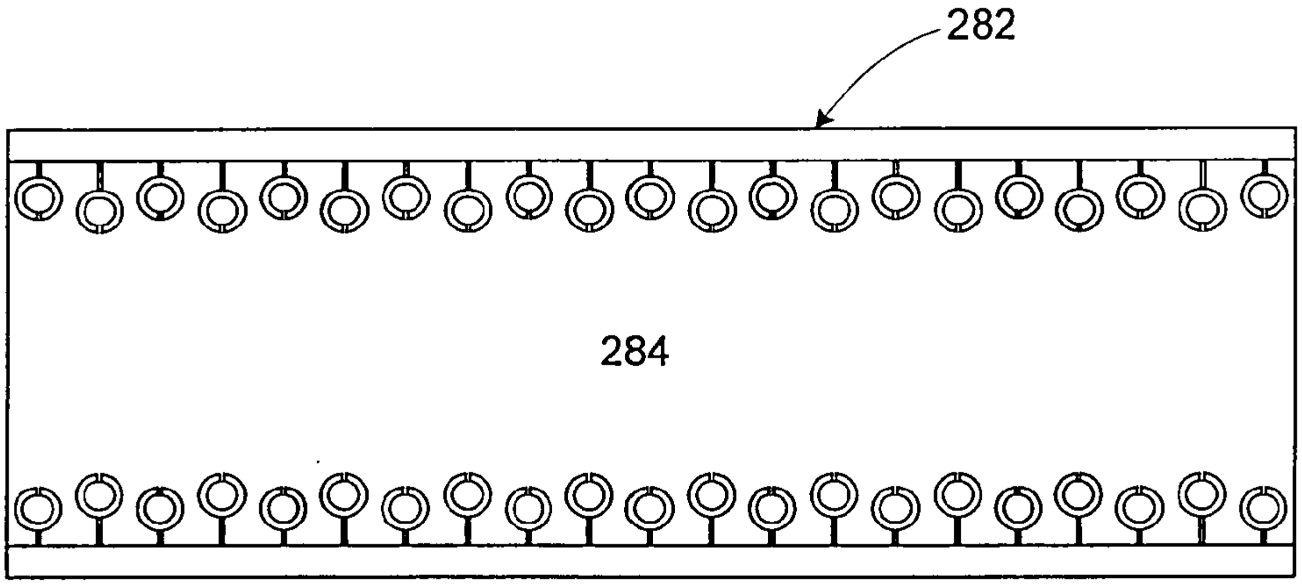


FIG. 32B

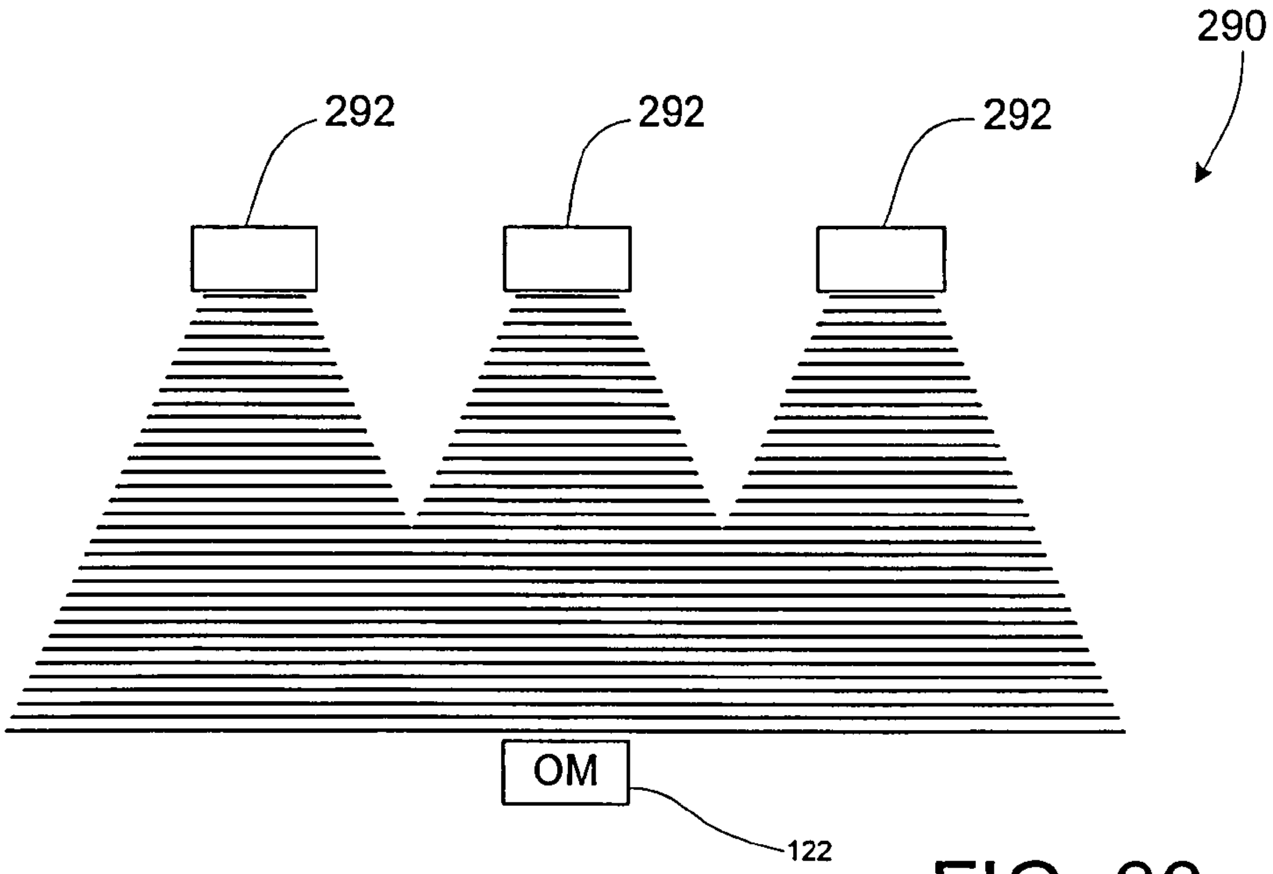


FIG. 33

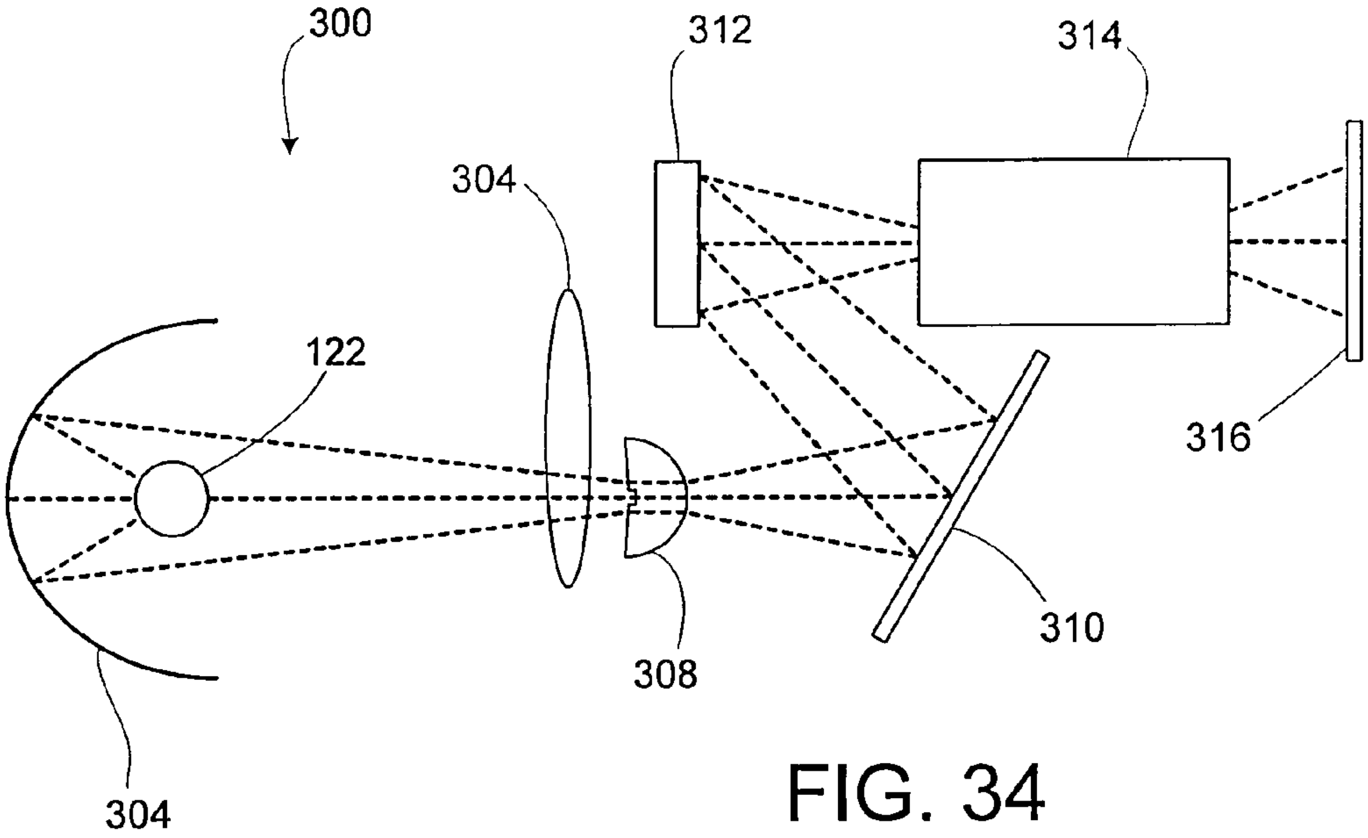


FIG. 34

OPTICAL MAGNETRON FOR HIGH EFFICIENCY PRODUCTION OF OPTICAL RADIATION AND RELATED METHODS OF USE

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 10/982,591, filed Nov. 5, 2004, now U.S. Pat. No. 7,265,360 which is hereby incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates generally to light sources, and more particularly to a high efficiency light source in the form of an optical magnetron and related applications.

BACKGROUND OF THE INVENTION

Magnetrons are well known in the art and have long served as highly efficient sources of microwave energy. For example, magnetrons are commonly employed in microwave ovens to generate sufficient microwave energy for heating and cooking various foods. The use of magnetrons is desirable in that they operate with high efficiency, thus avoiding high costs associated with excess power consumption, heat dissipation, etc.

Conventional microwave magnetrons employ a constant electric and magnetic field to produce a rotating electron space charge. The electron space charge interacts with a plurality of microwave resonant cavities to generate microwave radiation. Conventional magnetrons are efficient generators of microwave energy for frequencies in the 1 to 10 GHz region. At higher frequencies, the maximum output power drops and the required electric and magnetic field strength increases (at higher frequencies the resonant cavities become proportionally smaller). The practical upper frequency limit for conventional magnetron designs is about 100 GHz at about 1 Watt (W) of continuous power. By comparison, at 1 GHz, conventional magnetrons can produce several kilowatts of continuous power. In short pulses, most magnetron designs can produce peak powers 1000 times higher than their maximum continuous power levels. In pulse operation, multi-megawatt power levels are possible in the 1 to 10 GHz range.

Conventional magnetrons employ anodes which have a plurality of resonant cavities arranged around a cylindrical cathode. The resonant cavities typically number from six to twenty. They may be shaped as hole and slot-keyhole structures or as straight-sided pie-shaped structures. FIGS. **1**A-**1**C illustrate several conventional magnetron anode designs, namely, the slot-keyhole, the straight-sided pie-shaped structure and the rising sun structure (i.e., an anode with resonant cavities having varying dimensions), respectively.

Mode control is an important issue in magnetron operation. A mode is a collective oscillation of all of the resonant cavities. In a single mode, all of the cavities may oscillate at substantially the same frequency but with some phase difference between adjacent cavities. The most desirable mode of operation occurs when adjacent cavities oscillate 180 degrees out of phase with each other or pi radians out of phase. This is known as pi-mode, and is the most power efficient mode. Numerous other modes are possible. For example, all cavities can oscillate in phase with each other, which is known as the zero pi-mode. Another possibility is that adjacent cavities oscillate pi/2 radians or 90 degrees out of phase with each other. In general, the number of distinct possible modes equals the number of resonant cavities. As more cavities are added, the number of possible modes increases.

Without some sort of mode control device, a magnetron can and will oscillate at any possible mode. Each mode has a slightly different oscillation frequency and power efficiency. Without mode control, a magnetron oscillator will jump about in frequency and power level in an uncontrolled manner.

The frequency and power limitations of conventional magnetron designs arise from a breakdown of mode control. Mode control is conventionally accomplished either by using strapping rings **10** as shown in FIGS. **1**A and **1**B, or by alternating the size of the resonant cavities **12** as in the rising sun design of FIG. **1**C. As a practical matter, these prior art methods of mode control fail when the number of cavities exceed approximately twenty. Numbers higher than forty heretofore have been considered completely impractical.

Since the spacing of anode pole pieces depends directly on the operating wavelength, this limitation drives higher frequency designs to very small size and limits their power handling capability. The very small size also requires very large magnetic fields to maintain small radius electron orbits within the small device. At 100 GHz for example, the resonant cavities are reduced to a fraction of a millimeter in length. Such small pieces of metal may cause problems as a result of being unable to handle high-power levels without melting. Furthermore, as the anode diameter becomes smaller, impractically large magnetic fields are required to produce tighter electron orbits around the cathode.

With reference to FIG. **2**, a conventional cylindrical magnetron **14** is provided with a central electron emitting cathode **16** and a circumferential anode **18** containing a plurality of resonant cavities **12**. A high voltage source (not shown) is used to accelerate electrons from the cathode **16** to the anode **18** (the cathode is at negative potential and the anode is at positive potential), and an axial magnetic field **20** causes the electrons to follow curved orbits on their way from the cathode **16** to the anode **18**. A power coupling port **19** provides a means to deliver the energy away from the resonant cavities **12**. Planar (non-curved) magnetrons are also possible with similar operating principles. For clarity, only cylindrical magnetrons will be discussed.

During operation of the magnetron **14**, an electron cloud rotates about an axis of symmetry within an interaction space, e.g., the space between the anode and cathode. As the cloud rotates, the electron distribution becomes bunched on its outer surface, thereby forming spokes of electronic charge that resemble the teeth on a gear. The operating frequency of the magnetron is determined by how rapidly the spokes pass from one gap to the next in one half of the oscillation period. The electron rotational velocity is determined primarily by the strength of a permanent magnetic field and the electric field which are applied to the interaction region.

FIG. **3** illustrates an expanded view of a portion of a conventional magnetron anode **18** in pi-mode operation. For simplicity, the curved structure is drawn straight. When operating in the desired pi-mode, adjacent resonant cavities **12** oscillate out of phase with each other. The space between the cathode and anode is filled with a rotating electron cloud **22**. A high voltage accelerates the electrons from cathode **16** to anode **18** and supplies the electrical energy which is converted into microwave power.

At an instant of time during pi-mode operation, it can be seen that the microwave fringing fields **24** at the resonant cavity openings have alternating directions. The circulating electron cloud **22** sees electric fields across consecutive openings which go from plus to minus potential, then minus to plus, then plus to minus, etc. The result is that the surface of the metal pole pieces **26** between resonant cavity openings are alternately at either positive or negative potential. Since electrons are attracted to positive and repelled from negative potentials, pi-mode operation serves to efficiently bunch the electron cloud **22**.

The rotating electron cloud **22** interacts only with the fringing fields **24** between anode poles. The function of the multiplicity of microwave resonators **12** is to support and maintain the oscillating fringing fields **24**. As taught in commonly assigned U.S. Pat. No. 6,724,146, a multiplicity of microwave resonators is not necessary to produce magnetron operation. It is sufficient to provide a multiplicity of anode pole pieces that support pi-mode at fringing fields across the anode openings.

For many practical reasons, the distance D between anode openings is typically a fraction of the operating wavelength, such as, for example, one-tenth or one-hundredth of the operating free space wavelength. The anode circumference of a typical prior art microwave-oven magnetron is about one-half the guided-wave wavelength and contains ten resonators for a spacing D of about $\frac{1}{20}$ wavelength. It is also known as a practical matter that mode control fails for magnetrons constructed with more than approximately twenty resonant cavities **12**. From these two facts it can be seen that mode control is difficult when the circumference of the anode is larger than approximately one wavelength at the operating frequency.

Recently, the applicant has described a high frequency magnetron that is suitable for operating at frequencies heretofore not possible with conventional magnetrons. This high frequency magnetron is capable of producing high efficiency, high power electromagnetic energy at frequencies within the infrared and visible light bands, and which may extend beyond into higher frequency bands such as ultraviolet, x-ray, etc. As a result, the magnetron may serve as a light source in a variety of applications such as long distance optical communications, commercial and industrial lighting, manufacturing, etc. Such magnetron is described in detail in commonly assigned, U.S. Pat. No. 6,373,194 and U.S. Pat. No. 6,504,303, the entire disclosures of which are incorporated herein by reference.

This high frequency magnetron is advantageous as it does not require extremely high magnetic fields. Rather, the magnetron preferably uses a magnetic field of more reasonable strength, and more preferably a magnetic field obtained from permanent magnets. The magnetic field strength determines the radius of rotation and angular velocity of the electron space charge within the interaction region between the cathode and the anode. The anode includes a plurality of small resonant cavities which are sized according to the desired operating wavelength. A mechanism is provided for constraining the plurality of resonant cavities to operate in pi-mode. Specifically, each resonant cavity is constrained to oscillate pi-radians out of phase with the resonant cavities immediately adjacent thereto. An output coupler or coupler array is provided to couple optical radiation away from the resonant cavities in order to deliver useful output power.

Additionally, applicant has made further improvements to the magnetron, wherein the wavelength of operation may be in the microwave band, infrared light or visible light bands, or even shorter wavelengths. The magnetron converts direct current (dc) electricity into single-frequency electromagnetic radiation, and includes an array of phasing lines and/or inter-digitated electrodes that are disposed around the outer circumference of an electron interaction space. During operation, oscillating electric fields appear in gaps between adjacent phasing lines/inter-digitated electrodes in the array. The electric fields are constrained to point in opposite directions in adjacent gaps, thus providing pi-mode fields that are necessary for efficient magnetron operation. Such a magnetron is described in detail in commonly assigned U.S. Pat. No. 6,724,146, the entire disclosure of which is incorporated herein by reference.

Nevertheless, a strong need remains in the art for even further advances in the development of high frequency electromagnetic radiation sources. For example, a strong need remains for a device having improved operation at high frequencies, e.g., over 100 GHz, while operating at high power levels. More particularly, a strong need remains for a device which does not utilize multiple resonant cavities, thereby simplifying the construction of the magnetron. Such a device would offer greater design flexibility and would be particularly well suited for producing electromagnetic radiation at very short wavelengths and operating at high power levels.

SUMMARY OF THE INVENTION

One aspect of the invention relates to an electromagnetic radiation source. The electromagnetic radiation source includes an anode having a first conductor; a second conductor positioned relative to the first conductor; a plurality of inter-digitated pole pieces coupled to the first conductor or the second conductor, wherein adjacent pole pieces are separated by a gap; at least one mechanical phase reversal positioned along the first conductor or the second conductor, the mechanical phase reversal forcing a polarity change between pole pieces adjacent to the mechanical phase reversal. The electromagnetic radiation source further includes a cathode separated from the anode by an anode-cathode space; electrical contacts for applying a dc voltage between the anode and the cathode and establishing an electric field across the anode-cathode space; and at least one magnet arranged to provide a dc magnetic field within the anode-cathode space generally normal to the electric field.

Other aspects of the invention are directed to an exemplary electromagnetic radiation source (e.g., optical magnetron) in a variety of systems including a welding system, a process heating system, an optical power transmission system, a wireless/high-bandwidth communications system, a cutting system, a lighting system, a medical diagnostics system, a medical therapy system, a system for killing insects, a system for killing plants, a directed energy weapon system, a system for converting direct current to optical power, a system for wirelessly providing electrical power to an aircraft, a system for wirelessly providing power to a satellite, a system for wirelessly transmitting electrical power from a space-based power generation station to earth, a pollution remediation system, a photochemical processing system, and a display system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic view of a prior art magnetron anode utilizing a slot-keyhole resonator design;

FIG. **1**B is a schematic view of a prior art magnetron anode utilizing a straight-sided pie-shape resonator design;

FIG. **1**C is a schematic view of a prior art magnetron anode utilizing resonators having various dimensions;

FIG. **2** illustrates a prior art magnetron utilizing the anode of FIG. **1**B;

FIG. **3** is an expanded view of a portion of the anode of the magnetron of FIG. **2** during pi-mode operation;

FIG. **4** is an isometric view of an exemplary anode in accordance with an embodiment of the invention;

FIG. **5**A is a schematic view of the rings of the exemplary anode of FIG. **4**;

FIG. **5**B is a schematic view of the rings of the exemplary anode of FIG. **4**, illustrating the mechanical phase reversals;

FIG. **6**A is a sectional view of the exemplary anode of FIG. **4** during pi-mode operation;

FIG. **6**B is a sectional view of the exemplary anode of FIGS. **4** and **5** during pi-mode operation, illustrating the effect of the mechanical phase reversal;

FIG. **7**A is a graph illustrating the Q-factor of an embodiment of the exemplary anode in accordance with the invention with respect to prior art anodes and, more particularly, FIG. **7**A shows standing wave resonances in an exemplary anode with a circumference of 2 free-space wavelengths;

FIG. **7**B is a graph of the output power from an embodiment of the exemplary anode in accordance with the invention during operation in pi-mode (Note that mechanical phase reversals have preferentially selected oscillation at only one of the modes);

FIG. **8**A is an isometric view of an exemplary magnetron incorporating an exemplary anode in accordance with an embodiment of the present invention;

FIG. **8**B is a top view of the exemplary magnetron of FIG. **8**A;

FIG. **9** is an isometric view of an anode in accordance with another embodiment of the invention;

FIG. **10** is an isometric view of an anode in accordance with yet another embodiment of the invention;

FIG. **11** is an isometric view of an anode and coupling probes in accordance with an embodiment of the invention;

FIG. **12** is a schematic view of several probes in accordance with an embodiment of the invention;

FIG. **13** is a schematic view of the rings of the anode of FIG. **4** illustrating the coupling pins between conductors;

FIG. **14**A is an isometric view on an anode structure in accordance with another embodiment of the invention;

FIG. **14**B is an isometric view on an anode structure in accordance with yet another embodiment of the invention;

FIG. **15** is an isometric view of three stacked anodes in accordance with an embodiment of the invention.

FIG. **16** is a schematic diagram illustrating an exemplary optical magnetron in a system for providing wireless/high-bandwidth communications in accordance with the present invention;

FIG. **17** is a schematic diagram illustrating a wireless/high-bandwidth communications system including an exemplary optical magnetron in accordance with the present invention;

FIG. **18** is a schematic diagram illustrating an exemplary optical magnetron as part of a communication system for wirelessly transmitting and receiving data in accordance with the present invention;

FIG. **19** is a schematic diagram illustrating an exemplary optical magnetron in a point-to-multipoint system for transmitting data in accordance with the present invention;

FIG. **20** is a schematic diagram illustrating an exemplary optical magnetron in a microwave process heating system in accordance with the present invention;

FIG. **21** is a schematic diagram illustrating an exemplary optical magnetron in a welding system in accordance with the present invention;

FIG. **22** is a schematic diagram illustrating an exemplary optical magnetron in a system for providing medical diagnostics and/or treatments in accordance with the present invention;

FIG. **23** is a schematic diagram illustrating an exemplary optical magnetron included in a system that can be used for applying optical energy to a broad area;

FIG. **24** is a schematic diagram illustrating an exemplary optical magnetron in a system for irradiating grain;

FIG. **25** is a schematic diagram of an exemplary optical magnetron in a pollution remediation system;

FIG. **26** is a schematic diagram illustrating an exemplary optical magnetron as part of a directed energy weapon in accordance with the present invention;

FIG. **27** is a schematic diagram illustrating an exemplary optical magnetron as part of a missile target seeking system in accordance with the present invention;

FIG. **28** is a schematic diagram illustrating an exemplary optical magnetron in a system for wirelessly transmitting electrical energy in accordance with the present invention;

FIG. **29** is a schematic diagram illustrating an exemplary optical magnetron in a system for providing electric power to an aircraft in accordance with the present invention;

FIG. **30** is a schematic diagram illustrating an exemplary system for wirelessly providing power to a satellite in orbit;

FIG. **31** is a schematic diagram illustrating an exemplary optical magnetron in a system for transmitting power from an orbiting power generation station in accordance with the present invention;

FIG. **32**A is cross-sectional view taken along the diameter of an exemplary optical power cable for use in connection with such exemplary optical power transmission systems as described in, for example, FIG. **21**;

FIG. **32**B is a cross-sectional view taken along the longitudinal axis of an exemplary optical power cable for use in connection with such exemplary optical power transmission systems as described in, for example, FIG. **21**;

FIG. **33** is a schematic diagram illustrating an exemplary optical magnetron in a lighting system in accordance with the present invention;

FIG. **34** is a schematic illustration of an exemplary optical magnetron in a display system in accordance with the present invention.

DESCRIPTION OF THE INVENTION

The following is a description of the present invention with reference to the attached drawings, wherein like reference numerals will refer to like elements throughout. To illustrate the present invention in a clear and concise manner, the drawings may not necessarily be to scale.

The applicants have discovered that large anodes, e.g., anodes with a circumference larger than one free-space wavelength, exhibit traveling waves along the inner circumference of the anode. In other words, the surface of the anode supports creeping waves that propagate around the circumference of the anode in both clockwise and counterclockwise directions. The traveling waves change phase as they travel around the anode and, at certain operating frequencies, look like standing waves, e.g., they are in phase with themselves as they complete one revolution around the anode. These stationary or standing modes perturb and control the phase of the individual resonators, thereby making pi-mode operation for conventional magnetron anodes sometimes difficult or impossible to achieve.

Referring to FIG. **4**, an anode **30** in accordance with an embodiment of the present invention is shown. The anode **30** need not include discrete microwave resonators. Instead, resonance is provided by standing wave modes and pi-mode electric fields are developed in conjunction with multiple poles having gaps formed between adjacent poles, wherein the length of the run is greater than the operating wavelength λ, preferably greater than 2λ, and more preferably greater than 3λ. Additionally, in accordance with the present invention a mechanical phase reversal of the poles is introduced every ½λ of the standing wave. Note that the wavelength of the standing and traveling waves is much shorter (about 5-times shorter) than the wavelength of a free-space wave of similar frequency. As used herein, a "run" refers to the length of the anode. An annular anode, for example, has a run that is equal to the circumference of the anode. A flat anode, on the other hand, has a run that is equal to the length of the anode.

In the embodiment of FIG. **4**, the anode includes an annular top conductor **32** and an annular bottom conductor **34**. The annular conductors have a radius "r" and are arranged to be concentric with respect to each other. A plurality of pins **36**, which form a "ring of pins" within the anode **30**, have a length "L" and are electrically coupled to the top conductor **32** or to the bottom conductor **34** and extend therefrom, wherein the pins each are separated from adjacent pins by a gap "G". The pins **36** function as anode pole pieces and, as will be discussed below, the gaps between the pins **36** provide fringing fields which interact with a rotating electron cloud (not shown).

The practical limit for the number of pins can be thousands or even millions of pins in a single anode. The large number of pins allows the fabrication of large devices with high power capability that can operate at higher frequencies and shorter wavelengths than magnetrons using conventional anode designs. Moreover, the large devices require only modest magnetic fields for operation.

The radius r of the anode **30** can vary depending on the requirements of the specific application. The length L of the pins affects the frequency of operation of the magnetron. Longer pins reduce the frequency of operation, while shorter pins increase the frequency of operation. Similarly, the pin gap G between pins also affects the frequency of operation of the magnetron. In one embodiment, the gap or spacing between pins is such that there are 10 to 20 pins per standing wavelength along the circumference of the anode. The cross sectional shape of the pins can be rectangular, triangular, circular, or any other geometrical shape.

The top and bottom conductors **32**, **34** of the anode **30** may be viewed as conductors in a parallel wire transmission line, wherein the transmission line is connected back upon itself in a large circle. As was noted above, some pins **36** are connected to the top conductor, while other pins are connected to the bottom conductor. FIG. **5**A illustrates this aspect of the anode, wherein top pins **36***a* are connected to the top conductor **32**, and bottom pins **36***b* are connected to the bottom conductor **34**. Generally speaking, the pins **36** are configured so as to provide an inter-digitated structure. More specifically, top pins **36***a* of the top conductor **32** mesh with bottom pins **36***b* of the bottom conductor **34**. As used herein, mesh refers to an alternating pattern between at least two objects, wherein the objects do not contact one another.

The pins **36** connect to a voltage generated by the standing microwave fields on the ring. With reference to FIG. **6**A, which is a cross sectional view of the anode of FIG. **5**A taken along the section A-A, voltages between adjacent pins **36***a*, **36***b* provide fringing fields **24** that can interact with the circulating electron cloud **22**. More specifically, the fringing fields **24** between the pins **36***a*, **36***b* exactly replicate the pi-mode fields of prior art magnetrons devices. Thus, the anode of the present invention can operate in pi-mode without the need for mode control mechanisms, e.g., strapping rings of prior art anodes.

For certain discrete frequencies, the inner circumference of the anode **30** equals an integer number of standing half wavelengths of the operating microwave frequency. At these resonance conditions, the traveling waves of microwave energy are in phase with themselves after each trip around the circumference of the ring and form standing waves. The result is a very high-Q low-loss resonance at a microwave frequency. FIG. **7**A shows the results of resonance measurements in a ring of one hundred twenty pins for several modes. More specifically, the discrete modes in a ring of one hundred twenty pins show Q-values around or above 500. The Q of a conventional magnetron resonator is on the order of 100. Thus, the anode of the present invention, when utilized in a magnetron, offers a significant improvement in the Q factor when compared to magnetrons utilizing prior art anodes.

At approximately every half standing wavelength around the ring, the connecting pins **36** are provided with a mechanical phase reversal **38** as shown in FIG. **5**B. The microwave standing waves on the ring go through an electrical phase reversal at every half wavelength, and the mechanical phase reversal **38** forces a polarity change between the top pins **36***a* and the bottom pins **36***b* that corresponds with the phase reversal of the standing waves. In other words, the mechanical phase reversal compensates for the microwave phase reversal and, thus, presents continuously in-phase pi-mode fields to the circulating electrons. The mechanical phase reversal ensures that a particular mode of operation, such as a desired single operating frequency, for example, is maintained. FIG. **7**B shows the microwave output power from the anode of FIG. **7**A where the mechanical phase reversals have been designed to select only one of the possible standing wave modes. The result is a pure single mode operation. As will be appreciated by those skilled in the art, one or more mechanical phase reversals **38** can be placed along the anode to support a single operating mode at any of the possible anode resonances.

The orientation of the phase reversals **38** can alternate between the top conductor **32** and the bottom conductor **34**. For example, a first mechanical phase reversal can have both pins coupled to the top conductor **32**, and the next mechanical phase reversal can have both pins coupled to the bottom conductor **34**.

The mechanical phase reversal can be implemented, for example, by forming the pins **36** such that two pins connected to the same conductor are adjacent to each other. In other words, the pins of one conductor, e.g., the top conductor **32**, do not mesh with corresponding pins of the other conductor, e.g., the bottom conductor **34**. By this manner, the circulating electrons continually see pi-mode fields which do not reverse in phase and which remain synchronous with the electron motion. The spacing between pins of the mechanical phase reversal is the same as the spacing between other pins, e.g., a gap "G" between pins of the mechanical phase reversal.

The position of the standing wave can float or drift along the surface of the anode. To anchor the position of the standing wave, a shorting bar **36***c* is electrically coupled between the top conductor **32** and the bottom conductor **34**, thereby providing a solid reference point. More specifically, the shorting bar **36***c* is placed between one pair of mechanical phase reversals **38**. Any remaining mechanical phase reversals do not include the shorting bar **36***c*. With the shorting bar **36***c*, the location of the standing wave is fixed.

FIG. **6**B, which is a cross sectional view of the anode of FIG. **5**B taken along section B-B, illustrates the effect of the mechanical phase reversal **38** on pi-mode operation. As was previously described, the pins **36** connect to a voltage generated by the standing microwave fields on the ring. Assuming a negative charge develops on a first top pin **36***a***1** and a positive charge develops on an adjacent bottom pin **36***b***1**, then a negative charge develops on the next top pin **36***a***2**, while a positive charge develops on the next adjacent bottom pin **36***b***2**. This pattern, e.g., negative (top pin)-positive (bottom pin), negative (top pin)-positive (bottom pin), etc., continues as before until the mechanical phase reversal **38**.

At the mechanical phase reversal **38**, two bottom pins **36***b***3**, **36***b***4** are adjacent to each other. Following the above pattern, a positive charge develops on bottom pin **36***b***3**, a negative charge develops on adjacent bottom pin **36***b***4**, and a positive charge develops on the next top pin **36***a***4**. Thus, the polarity of the top and bottom pins has been shifted or reversed. Moreover, this reversal corresponds to the phase reversal of the standing waves. Thus, even though the standing waves undergo a phase reversal, thereby changing the polarity of the standing wave voltage, the mechanical phase reversal **38** compensates for the polarity change by changing the polarity of the top and bottom pins, thereby replicating the pi-mode fields of prior art magnetrons and therefore maintaining pi-mode operation. The shorting bar **36***c* locks the position of the standing wave on the anode.

FIGS. **8**A and **8**B illustrate a magnetron **14'** incorporating an anode **30** in accordance with an embodiment of the present invention. The magnetron includes the anode **30** and a cathode **16** separated by an interaction space (or anode-cathode space), electrical contacts +V, −V for applying a voltage to the anode and cathode, and a magnet (not shown), which produces a magnetic field **20**. Operation of the magnetron **14'** will now be described.

A high voltage (not shown) is applied between the cathode **16** and anode **30** via the contacts +V, −V as is conventional, and the high voltage accelerates electrons from the cathode to the anode, thereby creating a circulating electron cloud **22**. As the cloud moves through an interaction space (e.g., the space between the anode and cathode), traveling wave modes, which prevent mode control in magnetrons utilizing conventional anodes, form and develop a charge on the pins **36** that creates fringing fields **24**. The fringing fields **24** replicate pi-mode fields of prior art magnetrons. More specifically, and with further reference to FIG. **6**B, the traveling wave modes create a resonance whereby a negative charge develops on a first pin **36***a***1** and a positive charge develops on an adjacent pin **36***b***1**. The next adjacent pin **36***a***2** develops a negative charge and the next adjacent **36***b***2** pin develops a positive charge, etc. The circulating electron cloud **22** interacts with the developed charge, e.g., electrons are attracted to the positive charge and repelled from the negative charge, thereby efficiently bunching the electron cloud. As the standing waves go through an electrical phase reversal, which occurs at every half wavelength, the mechanical phase reversals **38** force a change in polarity of the pins **36**, as shown in FIG. **6**B, thereby maintaining pi-mode operation.

The anode **30** of the present invention can be substantially larger than one-wavelength in circumference at the operating frequency while maintaining mode control. This is significant since magnetrons utilizing prior art anodes would experience failure of mode control when the circumference of the anode became larger than approximately one wavelength at the operating frequency. Additionally, the anode of the present invention permits large electron orbits and thus can operate using small magnetic fields at short wavelength operation. Furthermore, and unlike conventional magnetron anodes, the anode **30** permits mode control with a large number of pole pieces.

With reference to FIG. **9**, a forty pin structure in accordance with an embodiment of the anode is shown. The anode **30'** includes a supporting flange **40** integrally formed with the ring of pins **36**. During operation, the traveling waves, which circulate about the ring of pins, are closely attached to the space surrounding the pins **36**. Significant power levels extend outward from the ring by only about two pin spacings. Thus, the circulating power and mode frequency are largely unaffected by the addition of flanges or support structures. Additionally, the power stays near the pins and does not travel outward on the flanges. As should be appreciated, the size of the flange can vary based on the specific requirements. Moreover, various flange sizes will not degrade performance of the anode.

FIG. **10** illustrates a one hundred twenty pin structure in accordance with another embodiment of the anode. The anode **30"**, in contrast to the embodiment of FIG. **9**, has almost no supporting flanges. In both embodiments, output coupling probes **42** are placed closely to the pins **36** to couple to the tightly bound circulating power, as illustrated in FIG. **11**. The coupling probes provide a means to deliver the energy from the pins to a remote area or device. The coupling probes can be capacitively and/or inductively coupled to the anode. Inductively and capacitively coupled probes should be placed within two pin-spacings of the ring of pins **36**. FIG. **12** illustrates several embodiments of coupling probes, including inductive loops **44**, small metal antennas **46**, and dielectric probes **48** that sample the electric field of the circulating waves.

Alternatively, the coupling probes can be directly connected to the anode via one of the mechanical phase reversals **38**. For example, a first conductor can be coupled to one pin of a mechanical phase reversal, and a second conductor can be coupled to a second pin of the same mechanical phase reversal, wherein the power output is the differential between the two conductors. The conductors can be coupled at the midpoint of the each respective pin of the mechanical phase reversal.

In addition to annular shaped anodes, non-annular structures also are practical. Similar microwave resonances found in annular shaped anodes are observed in straight or curved sections of transmission lines that are provided with short-circuit pins **36***d* at their ends, as shown in FIG. **13**.

For practical designs that may require very large numbers of pins, it is feasible to break up a large ring into several sectors. Non-ring structures may be used as stand-alone arcs in very large cylindrical magnetrons. An optical resonator can be employed with the arcs to enhance performance at short operating wavelengths. Non-ring structures also can be used in planar (cylindrical) magnetrons devices. Alternatively, a large anode may be formed from several independent subsections that are coupled together to form the anode structure.

For example, and with reference to FIG. **14**A, four arcs **50** are used to form a general anode structure. The arcs **50** are similar to the anode **30**, except they do not form one continuous anode structure, and they include shorting pins **36***d* at the ends of each arc. Each arc is separated from an adjacent arc by a gap G**1**, wherein G**1** is an integer multiple of the gap G between adjacent pins of the arc. Each arc includes a top conductor **32'** and a bottom conductor **34'**, and a plurality of pins **36** connected to the top, bottom or both conductors as previously described. FIG. **14**B illustrates an anode similar to the anode of FIG. **14**A, except the anode is formed from four separate arcs **50'** that are coupled together to form a continuous anode structure. Each arc includes a top conductor **32"** and a bottom conductor **34"**, and a plurality of pins **36** connected to the top, bottom or both conductors.

Anodes in accordance with the present invention may be stacked one above another as shown in FIG. **15**. Stacking allows the anode to have a larger area and higher power handling capability than would be possible with a single ring anode design. Additionally, anodes **30** preserve their high-Q low-loss resonance when stacked, provided a minimal spacing “K” exists between the anodes. In general the spacing K between anodes should be no smaller than the spacing G between adjacent pins **36** in the anode. If the spacing K is on the order of two pin spacings, the anodes interact sufficiently to induce frequency locking between anodes. In this manner, a single pi-mode resonator may be constructed with thousands of times the area and power handling capability of conventional magnetrons anode designs.

Accordingly, an anode for use in a magnetron has been disclosed that permits single mode operation while including substantially more than one-hundred pole pieces. Moreover, the anode eliminates the prior art requirement for a multiplicity of microwave resonators. The multiplicity of resonators are replaced with a ring of pins, which serve to provide a high quality microwave resonance and to present pi-mode electric fields to the circulating electron cloud. The circumference of the anode can be substantially larger than one-wavelength of the operating frequency, and the anode, whether cylindrical or planar, may be stacked for large area and high power handling capability. Furthermore, the anode in accordance with the present invention permits large electron orbits and, therefore, small magnetic fields at short wavelength operation. The anode also may be segmented into multiple sectors, thereby facilitating the fabrication of large anode designs.

Turning to FIG. **16**, an exemplary optical magnetron **122** is shown in a system **120** for providing wireless/high-bandwidth communications. The system **120** includes a transmitting optical magnetron **122** for transmitting electromagnetic radiation, and an optical receiver **123** for receiving electromagnetic radiation emitted from the transmitting optical magnetron **122**. The transmitting optical magnetron **122** and optical receiver **123** are mounted on a tower **124** and can be connected to one or more servers **125** or computers that in turn are connected to a broadband network. It will be appreciated that the optical receiver **123** can be a conventional microwave magnetron or another device capable of receiving the electromagnetic radiation transmitted by the transmitting optical magnetron **122**. A fixed or mobile user **126** within range of the tower **124** is provided with a transmitter and a receiver. Data can be transmitted over the system **120** using communication protocols similar to that used in other optical transmission systems. By utilizing the high power optical magnetron of the present invention, higher data-transfer rates can be achieved and many more end-users can be serviced from a given tower than in conventional systems. In addition, the greater ranges that are achievable with the optical magnetron of the present invention means fewer towers are needed to service a given area. Further details of the wireless/high-bandwidth communications systems are set forth in U.S. patent application Ser. No. 10/231,651 filed on Aug. 30, 2002, which is hereby incorporated herein by reference in its entirety.

Turning to FIG. **17**, another wireless/high-bandwidth communications system **130** including an exemplary optical magnetron **122** in accordance with the present invention is shown. This system **130** is identical to the system **120** shown and described in connection with FIG. **16**, except that instead of being mounted on a tower, a transmitting optical magnetron **122** and optical receiver **123** are mounted on a satellite **132** in orbit around earth. In the past, satellite communication has been limited to a relatively small portion of the microwave spectrum, which in turn has limited the available data rates. Accordingly, ground services which have almost unlimited bandwidth for long-haul applications have kept such satellite communications systems from becoming mainstream. Using the optical magnetron **122** of the present invention enables new frequency bands to be exploited for satellite communications services. By opening up larger portions of spectrum, a satellite system using the optical magnetron of the present invention will be able to directly compete with ground wired systems in terms of delivered bandwidth.

In FIG. **18**, an exemplary optical magnetron in accordance with the present invention is shown as part of a communication system **140** for wirelessly transmitting and receiving data. Data can be transmitted over the system **140** using communication protocols similar to that used in other optical transmission systems, such as the system **120** of FIG. **16**. The system **140** includes first and second transmitting optical magnetrons **122** for transmitting optical energy and a first and second optical receivers **123** for receiving transmitted optical energy. Each optical magnetron **122** and optical receiver **123** is connected to a land-based network **146**, such as a landline telephone network for transmitting telephone calls. The optical magnetrons **122** and optical receivers **123** can be mounted on towers **148** for increasing effective range. The system **140** can be part of a wireless communication system or network, commonly referred to as a cell phone network for transmitting and receiving voice calls and/or data between one or more wireless devices and/or one or more wired devices.

In FIG. **19**, an exemplary optical magnetron in accordance with the present invention is shown in a point-to-multipoint system **150** for transmitting data. As will be appreciated, data can be transmitted over the system **150** using communication protocols similar to that used in other optical transmission systems. The system **150** includes an optical magnetron **122** in accordance with the present invention configured to transmit data using electromagnetic energy to a plurality of subscribers **152**. The higher power transmission rates achievable with the optical magnetron **122** of the present invention results in higher data rates thereby permitting more subscribers to be serviced from a given central transmitter which may be mounted on a tower **154**. Greater ranges than currently achievable are also possible with the optical magnetron of the present invention thus further reducing the number of towers needed to service a given area.

Turning now to FIG. **20**, an exemplary optical magnetron **122** in accordance with the present invention is shown in a microwave process heating system **160**. Such a system **160** can be utilized in a microwave oven, for example. The system **160** includes an optical magnetron **122** and a power source **162** connected to the optical magnetron **122**. The optical magnetron **122** of the present invention greatly expands the power levels and available frequencies available to the process heating system **160** as compared to conventional systems.

FIG. **21** illustrates a system **170** for welding including an exemplary optical magnetron **122** in accordance with the present invention. The system **170** includes a power source **172**, an optical magnetron **122**, and a welding wand **174** connected to the optical magnetron **122** via a fiber optic cable for directing the optical energy emitted by the optical magnetron **122**. The system **170** can also be used for cutting various metals by heating the metal, similar to the manner in which a blowtorch is used to cut metal. Energy from the optical magnetron **122** can be focused on a target area via a focusing means (e.g., within the wand), thereby heating and/or cutting the metal.

Turning to FIG. **22**, an exemplary optical magnetron **122** in accordance with the present invention is shown in a system **180** for providing medical diagnostics and/or treatments. The optical magnetron **122** is configured to direct electromagnetic energy at a patient **182** to facilitate, for example, body scanning and/or imaging. The system **180** can also be used to direct treatment energy, such as tissue-penetrating microwaves for hyperthermic treatment, at the patient **182**.

In FIG. **23**, an exemplary optical magnetron **122** in accordance with the present invention is included in a system **190** that can be used for applying optical energy to a broad area, such as an agricultural field **192**, for example. Energy from the optical magnetron **122** can be scanned over a target area at a particular wavelength and/or energy level etc. via a focusing means (e.g., a wave guide). Such a system **190** can be utilized for exterminating insects and/or for destroying vegetation, such as weeds. It will be appreciated that, by modulating the intensity and/or wavelength of the directed energy, certain types of vegetation and/or insects may survive while other types are eliminated. Accordingly, the system **190** can be used as a selective herbicide/insecticide to eliminate only unwanted vegetation and/or insects while leaving desired vegetation and/or insects unharmed. The system **190** can also be used to destroy seeds prior to germination thereby "sanitizing" soil prior to planting crops. The system **190** can be mounted to a vehicle, such as a tractor or an aircraft **194**, or can be provided in a portable form factor that can be used in smaller applications, such as in the household. The optical magnetron of the present invention could also enable such a system, mounted on a satellite, to be operated remotely from space.

Another application of agricultural pest control is irradiation of grain. In FIG. **24**, an exemplary optical magnetron **122** in accordance with the present invention is shown in a system **200** for irradiating grain as it enters a storage silo **202**. It will be appreciated that such a system **200** can be used to irradiate grain at other times and locations, such as when loading or unloading grain from a hold on a ship.

In FIG. **25**, an exemplary optical magnetron **122** in accordance with the present invention is included in a pollution control and/or remediation system **210**. The system **210** directs optical energy of suitable frequency and intensity at a polluted medium **212**, such as air, for destroying and/or catalyzing pollutants **214**. The system **210** can be ground based, mounted on an aircraft, or satellite based. The system **210** can be configured to treat air in the atmosphere (e.g., by broadly directing optical energy at the atmosphere). Alternatively, air can be drawn through a chamber and optical energy can be directed at the air as it passes therethrough. Alternatively, smaller versions of the system **210** can be configured to treat emissions from industrial processes and/or motor vehicle emissions. Accordingly, the system **210** can be mounted to a smokestack of a powerplant or a tailpipe of a vehicle. The system **210** can also be used in a conventional type air purifier.

In FIG. **26**, an exemplary optical magnetron **122** in accordance with the present invention is shown as part of a directed energy weapon **220**. The directed energy weapon **220** includes a power source **222**, the optical magnetron **122**, and a focusing device **224** for focusing energy emitted from the optical magnetron at a target. The directed energy weapon can be vehicle mounted, satellite mounted, or contained in a portable unit that can be carried by a user. Stationary units are also possible. The directed energy weapon **220** can be used to apply a lethal dose of energy to a live target **226** or can alternatively be configured to apply a less than lethal dose of energy for crowd control and other purposes. The directed energy weapon **120** can also be used to destroy electronic equipment or merely jam electronic equipment by delivering optical energy at a particular frequency.

In FIG. **27**, an exemplary optical magnetron **122** in accordance with the present invention is shown as part of a missile tracking system **230**. The missile tracking system **130** includes a power source **232**, a controller **234**, and an optical magnetron **122**. The system **230** can be ground-based or can be installed on an aircraft for tracking missiles and/or other projectiles and/or aircraft. Alternatively, the system can be mounted on a satellite. Such a system **230** can be used in conjunction with a missile defense system for tracking and deflecting and/or destroying enemy missiles before they reach their intended targets. In an exemplary embodiment, energy from the optical magnetron **122** is directed at an incoming missile in order to deflect the missile away from its intended target and/or to destroy the missile before impact with its intended target.

Turning to FIG. **28**, an exemplary optical magnetron in accordance with the present invention is shown as part of a system **240** for wirelessly transmitting electrical energy. The system **240** includes a power source or generator **242**, a transmitting optical magnetron **122** connected to the power source **242**, and a receiving optical magnetron **123** for receiving the wirelessly transmitted energy and converting it to electrical power. The power is transmitted in the form of electromagnetic energy. The electrical power can then be transmitted via existing power distribution lines to users **244**. Accordingly, power can be transmitted through the air between the transmitting optical magnetron **122** and the receiving optical magnetron **122**. As will be further described, however, the transmitting optical magnetron **122** and the receiving optical magnetron **122** can be coupled via a microwave cable, such as a fiber-optic cable, for transmitting optical energy. The system **240** can be used in place of high-voltage wire-based power transmission systems thereby eliminating high-voltage wires. This can be advantageous because microwave cables can be closely packed, unlike high-voltage wires, which permits increased capacity over existing utility right-of-ways. Further, microwave cables generally do not radiate possibly harmful electromagnetic fields to nearby structures or people.

Turning to FIG. **29**, an exemplary optical magnetron in accordance with the present invention is illustrated in a system **250** for providing electric power to an aircraft **252**. The system includes similar components to the above-described system **240** for wirelessly transmitting electrical energy, including a receiving optical magnetron **123** mounted on the aircraft **252** for receiving electromagnetic energy from a transmitting optical magnetron **122** and converting the energy into a electric power that can be used to power one or more electric motors to propel the aircraft **252**. Such a system **250** can be used to provide power not only for take-off and flight of manned or unmanned aircraft, but also for running onboard systems such as surveillance equipment, radar, etc. A tracking system **256** can be provided for tracking the aircraft and aiming the transmitting and/or receiving optical magnetrons **122** and **123** for efficient operation.

Similarly, FIG. **30** shows a system **260** for wirelessly providing power to a satellite **262** in orbit. The system includes an exemplary transmitting optical magnetron **122** in accordance with the present invention for transmitting optical energy to a receiving optical magnetron **123** aboard the satellite **262**. By transmitting power to the satellite **262** while in orbit, onboard power supplies can be smaller and/or eliminated altogether thereby reducing the weight of the satellite which in turn permits more efficient launching of the satellite. The system **260** can be used in connection with a geo-stationary satellite, in which case the transmitting optical magnetron **122** and satellite **262** are typically stationary relative to each other, and thus tracking the satellite **262** and aiming the optical magnetrons **122** is typically not critical. The system **260** can also be used with a satellite **262** that is not in a geo-stationary orbit. In such case, suitable tracking and aiming systems can be employed to aim the optical magnetrons **122** and **123**. As an example, for a satellite **262** that is only visible for a few hour period at a given location on earth, a tracking and aiming system **266** can be utilized to beam power to the satellite **262** when in visible range. The satellite **262** can be configured to operate off of battery power when not in visible range, or alternatively can shut down until power transmission is once again available.

Turning to FIG. **31**, an exemplary optical magnetron in accordance with the present invention is shown in a system **270** for transmitting power to earth from an extraterrestrial power generation station **272**. The system **270** includes the power station **272**, which can be an orbiting power station or could be located on a celestial object such as the moon or another planet, a transmitting optical magnetron **122** for transmitting the power generated by the power station **272** to a receiving optical magnetron **123** on earth **274**. For example, the system **170** could be used for transmitting power from a lunar-based solar energy farm or an orbiting nuclear power plant. The system of FIG. **31** has generally the same components as the above-described optical power transmission system **240** (FIG. **24**), and functions in essentially the same way. By removing power generation stations from the Earth's atmosphere, any pollution generated by such stations can be kept away from the Earth's atmosphere thereby providing environmental benefits. This is particularly the case for power generators such as nuclear power generators, which although provide a "clean" source of power still represent significant hazards to humans (radiation) in the event of a malfunction. Accordingly, the system of FIG. **24**, by permitting remote location of the powerplant, avoids pollution of the Earth's atmosphere and reduces the potential for malfunctions to adversely impact humans.

It will be appreciated that the above-described systems describing wireless optical transmission of data and/or electrical power transmission can be wireless or can include an optical cable for containing the optical energy. Turning to FIGS. **32**A and **32**B, an optical power cable for use in connection with such system is illustrated. The optical power cable **282** can be used to connect an exemplary transmitting optical magnetron **122** in accordance with the present invention to an energy receiving element, which maybe another exemplary optical magnetron. The optical power cable **282** can be a fiber-optic cable which permits the optical energy to travel within the cable with minimal losses and avoids scattering of the optical energy. Such a cable can also be useful in applications where line of sight aiming of the optical magnetron and energy receiving element is not possible.

The optical power cable **282** includes a generally transparent core material **284** having low absorption and scattering loss. The core material **284** can be glass, plastic, an inert gas, or a vacuum, for example. A cladding material **286** surrounds the core material **284** and serves to confine the optical power to the core material **284** and prevent leakage of the same from the cable **282**. Although typically little or no optical power flows in the cladding material **286**, the cladding material should preferably have low absorption and scattering loss.

Turning to FIG. **33**, an exemplary optical magnetron in accordance with the present invention is shown in a lighting system **290**. The system includes an optical magnetron **122** and one or more lighting units **292** that receive energy from the optical magnetron **122** and convert the energy to visible light. The lighting system **290** can be, for example, a microwave-powered electrodeless lighting system wherein the lighting units **292** are sulfur lamps consisting of a quartz bulb containing sulfur and inert argon gas at the end of a thin glass spindle. The optical magnetron **122** can be used to bombard the lamps with electromagnetic energy of a suitable wavelength to excite the gas thereby heating the sulfur into a brightly glowing plasma. Such lights can be used to replace conventional streetlights and offer potentially vastly higher efficiency than current gas discharge lamps and LED-based lamps. As an alternative, wireless energy transmitters (for example as illustrated in FIG. **23**) can be used in conjunction with conventionally powered lamps to provide electrical energy to generate light. An optical cable can also be used as desired.

An optical magnetron in accordance with the invention can also be used to directly generate visible light for lighting applications. In general, directly generating light with an optical magnetron in accordance with the invention is more efficient than generating light by other means, such as, thermal or gas discharge light sources or light emitting diodes (LEDs). For example, a single optical magnetron could be used to generate light for an entire office building. A network of fiber-optic cables could be used to distribute the light to emitting structures throughout the building.

Turning to FIG. **34**, an exemplary optical magnetron **122** in accordance with the invention is illustrated in an exemplary display system **300**. The display system **300** includes the optical magnetron **122** that functions as a light source, a mirror **304**, a color generator **306**, a condenser **308**, a reflector **310**, a spatial light modulator **312**, a projection lens **314**, and a display screen **316**. Light produced by the optical magnetron **122** travels along the illustrated path ultimately producing an image on the display screen **316**. It will be appreciated that the display system **300** is exemplary, and that the optical magnetron can be used as a light source in a wide variety of display systems including rear projection systems and projector systems. It will further be appreciated that the optical magnetron can be configured to directly produce pure colored visible light and that, therefore, the color generator **306** can be omitted in certain applications.

Although the description of some of the above-described systems includes the optical magnetron **122** as set forth in FIGS. **1-15**, it will be appreciated that is some applications other optical magnetrons can be utilized. Further, elements referred to as transmitters and receivers in the above-described systems can be optical magnetrons such as set forth above, or alternatively may be other optical magnetrons or other devices that can perform the transmitting and/or receiving functions.

Although the present invention has been described with reference to specific exemplary embodiments, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader spirit and scope of the invention as set forth in the claims. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

Although the invention has been shown and described with respect to a certain preferred embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

The following claims are in no way intended to limit the scope of the present invention to the specific embodiments described above. In addition, any recitation of "means for" is intended to evoke a means-plus-function reading of an element and a claim, whereas, any elements that do not specifically use the recitation "means for", are not intended to be read as means-plus-function elements, even if the claim otherwise includes the word "means".

What is claimed is:

1. An electromagnetic radiation source, comprising:

an anode comprising:

- a first conductor;
- a second conductor positioned relative to the first conductor;
- a plurality of inter-digitated pole pieces coupled to the first conductor or the second conductor, wherein adjacent pole pieces are separated by a gap;
- at least one mechanical phase reversal positioned along the first conductor or the second conductor, the mechanical phase reversal operable to force a polarity change between pole pieces adjacent to the mechanical phase reversal;
- a cathode separated from the anode by an anode-cathode space;

electrical contacts for applying a dc voltage between the anode and the cathode and establishing an electric field across the anode-cathode space; and

- at least one magnet arranged to provide a dc magnetic field within the anode-cathode space generally normal to the electric field.

2. An electromagnetic radiation source as set forth in claim **1** in combination with a welding wand for directing the electromagnetic radiation generated by the electromagnetic radiation source for welding.

3. An electromagnetic radiation source as set forth in claim **1** in combination with a power source for supplying power to the electromagnetic radiation source, the electromagnetic radiation source being adapted for process heating.

4. An electromagnetic radiation source as set forth in claim **1** in combination with a power source for supplying power to the electromagnetic radiation source, the electromagnetic radiation source being adapted for optical power transmission.

5. An electromagnetic radiation source as set forth in claim **1** in combination with a power source for supplying power to the electromagnetic radiation source, the electromagnetic radiation source being adapted for wireless/high-bandwidth communications.

6. An electromagnetic radiation source as set forth in claim **1** in combination with a wand for directing electromagnetic radiation generated by the electromagnetic radiation source for cutting.

7. An electromagnetic radiation source as set forth in claim **1** in combination with a lighting unit adapted to receive electromagnetic radiation from the electromagnetic radiation source and convert the radiation to visible light.

8. An electromagnetic radiation source as set forth in claim **1** wherein the electromagnetic radiation source is adapted for performing medical diagnostics.

9. An electromagnetic radiation source as set forth in claim **1** wherein the electromagnetic radiation source is adapted for performing medical therapy.

10. An electromagnetic radiation source as set forth in claim **1** wherein the electromagnetic radiation source is adapted for killing insects.

11. An electromagnetic radiation source as set forth in claim **1** wherein the electromagnetic radiation source is adapted for killing plants.

12. An electromagnetic radiation source as set forth in claim **1** in combination with a focuser adapted for focusing electromagnetic radiation generated by the electromagnetic radiation source at a target.

13. An electromagnetic radiation source as set forth in claim **1** wherein the electromagnetic radiation source is adapted to receive direct current and generate optical energy.

14. An electromagnetic radiation source as set forth in claim **1** in combination with an optical power receiver for receiving optical power from the electromagnetic radiation source and converting the optical power to direct current.

15. An electromagnetic radiation source as set forth in claim **1** in combination with a receive mountable to an aircraft, wherein the receiver is configured to receive electromagnetic radiation generated by the electromagnetic radiation source and convert the radiation to electrical power.

16. An electromagnetic radiation source as set forth in claim **1** in combination with a receive mountable to a satellite, wherein the receiver is configured to receive electromagnetic radiation generated by the electromagnetic radiation source and convert the radiation to electrical power.

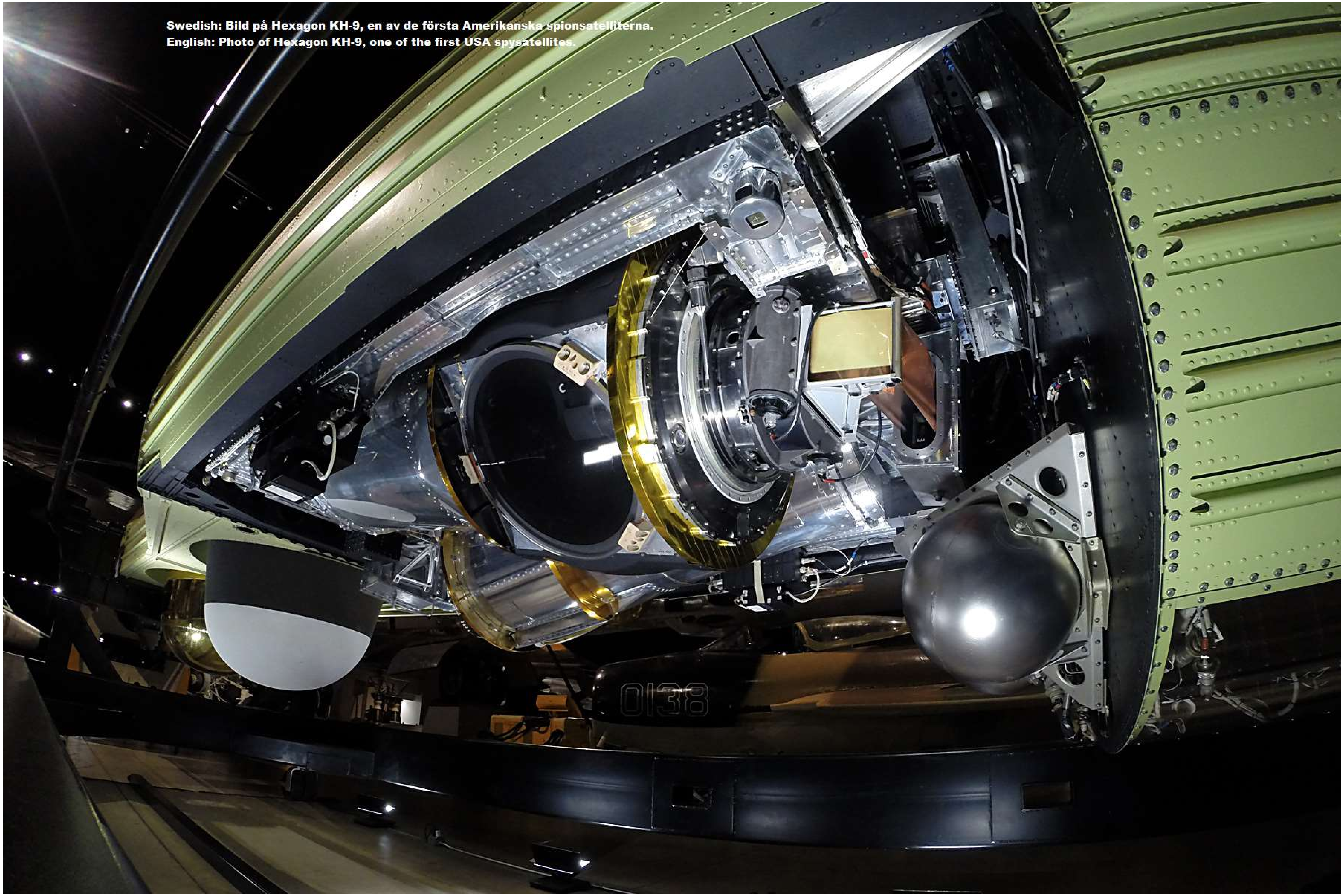
17. An electromagnetic radiation source as set forth in claim **1** in combination with space-based power generator and an earth-based receiver, wherein power generated by the space-based power generator is converted to electromagnetic radiation by the electromagnetic radiation source, and wherein the receiver is configured to receive electromagnetic radiation generated by the electromagnetic radiation source and convert the radiation to electrical power.

18. An electromagnetic radiation source as set forth in claim **1** wherein the electromagnetic radiation source is adapted for pollution remediation.

19. An electromagnetic radiation source as set forth in claim **1** wherein the electromagnetic radiation source is adapted for photochemical processing.

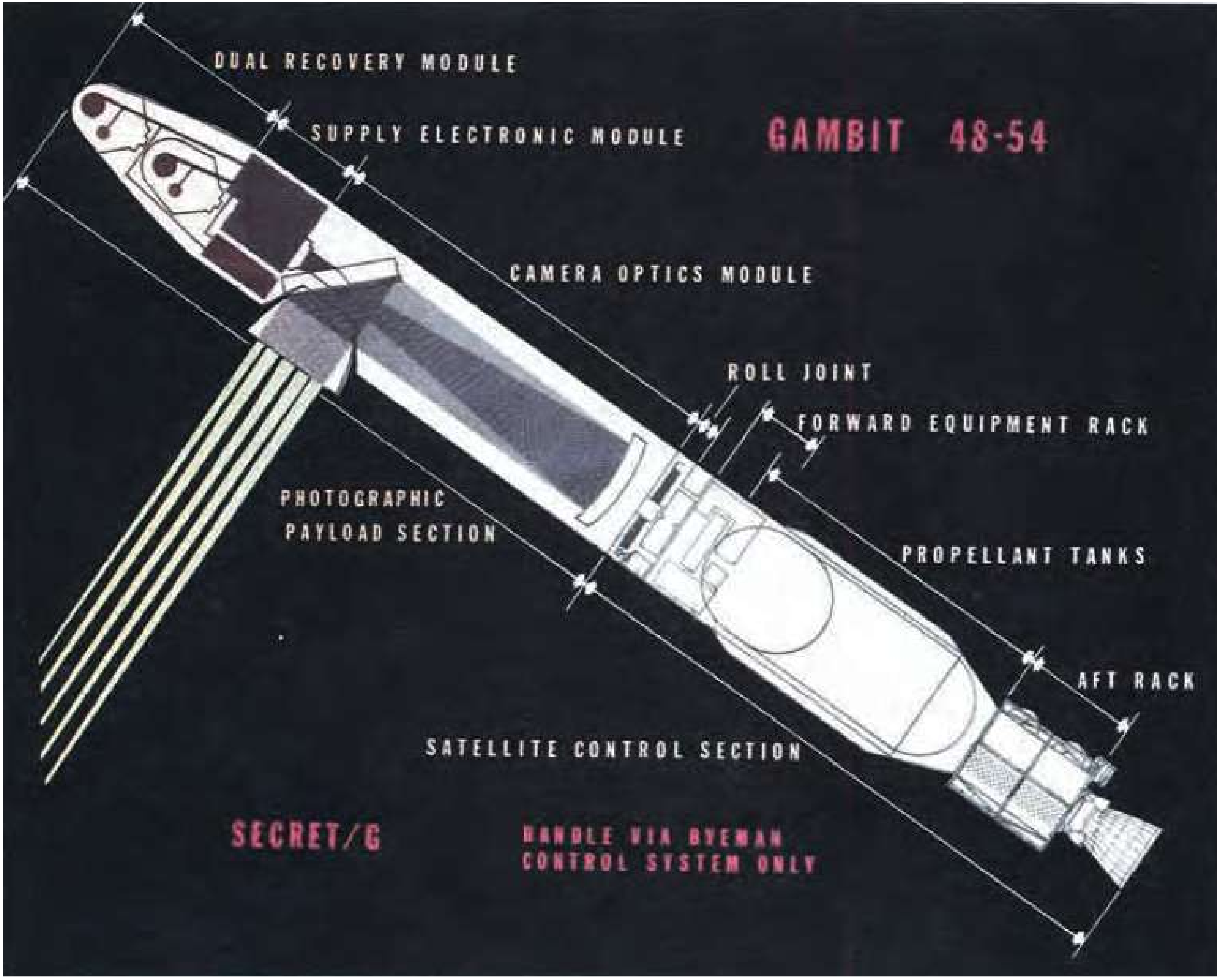
20. An electromagnetic radiation source as set forth in claim **1** in combination with a display surface, wherein the display surface is configured to display an image in response to radiation generated by the electromagnetic radiation source.

* * * * *



Swedish: Bild på Hexagon KH-9, en av de första Amerikanska spionsatelliterna.
English: Photo of Hexagon KH-9, one of the first USA spysatellites.

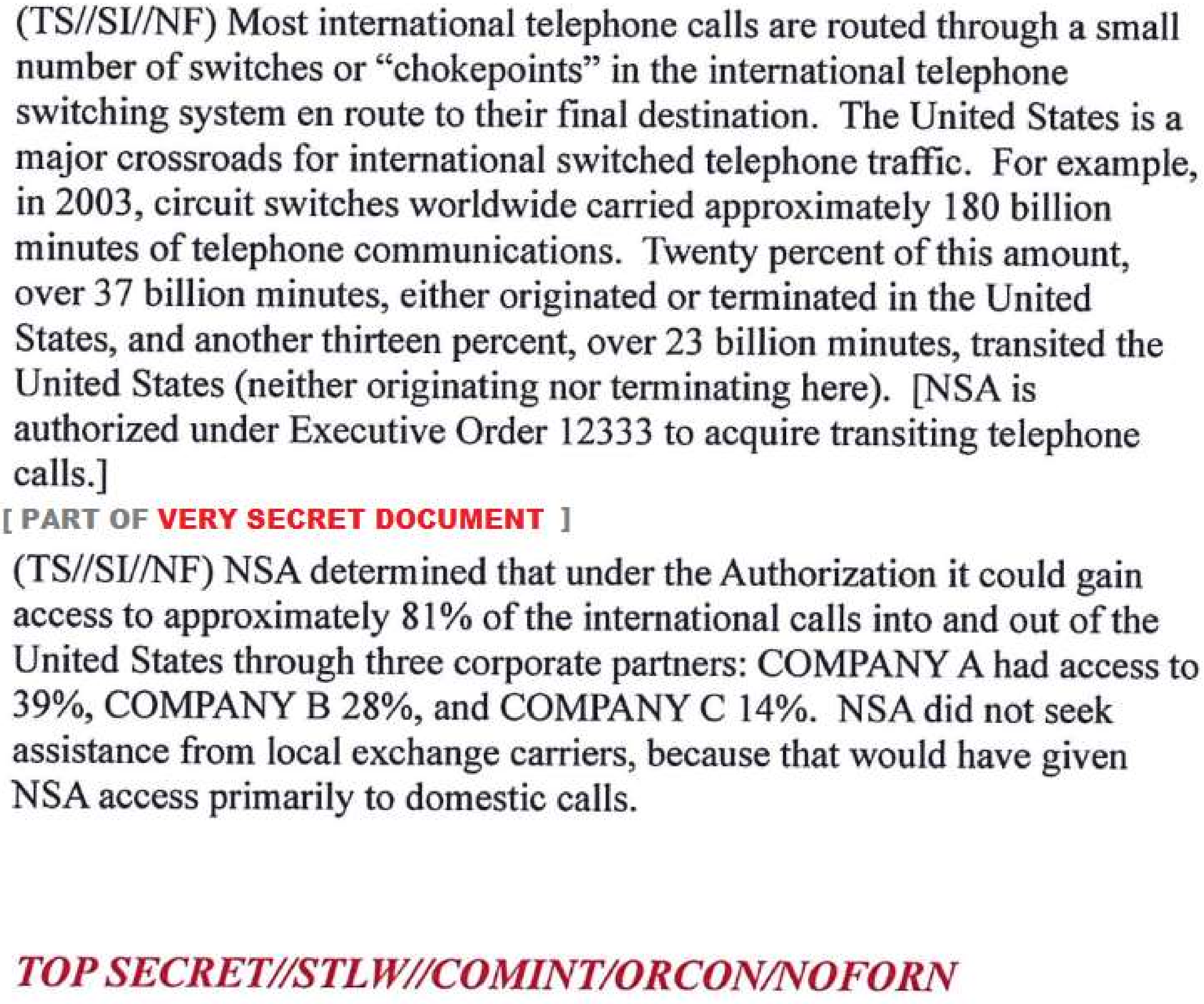
GAMBIT 48-54



SECRET/G

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY

(U//FOUO) Telephony



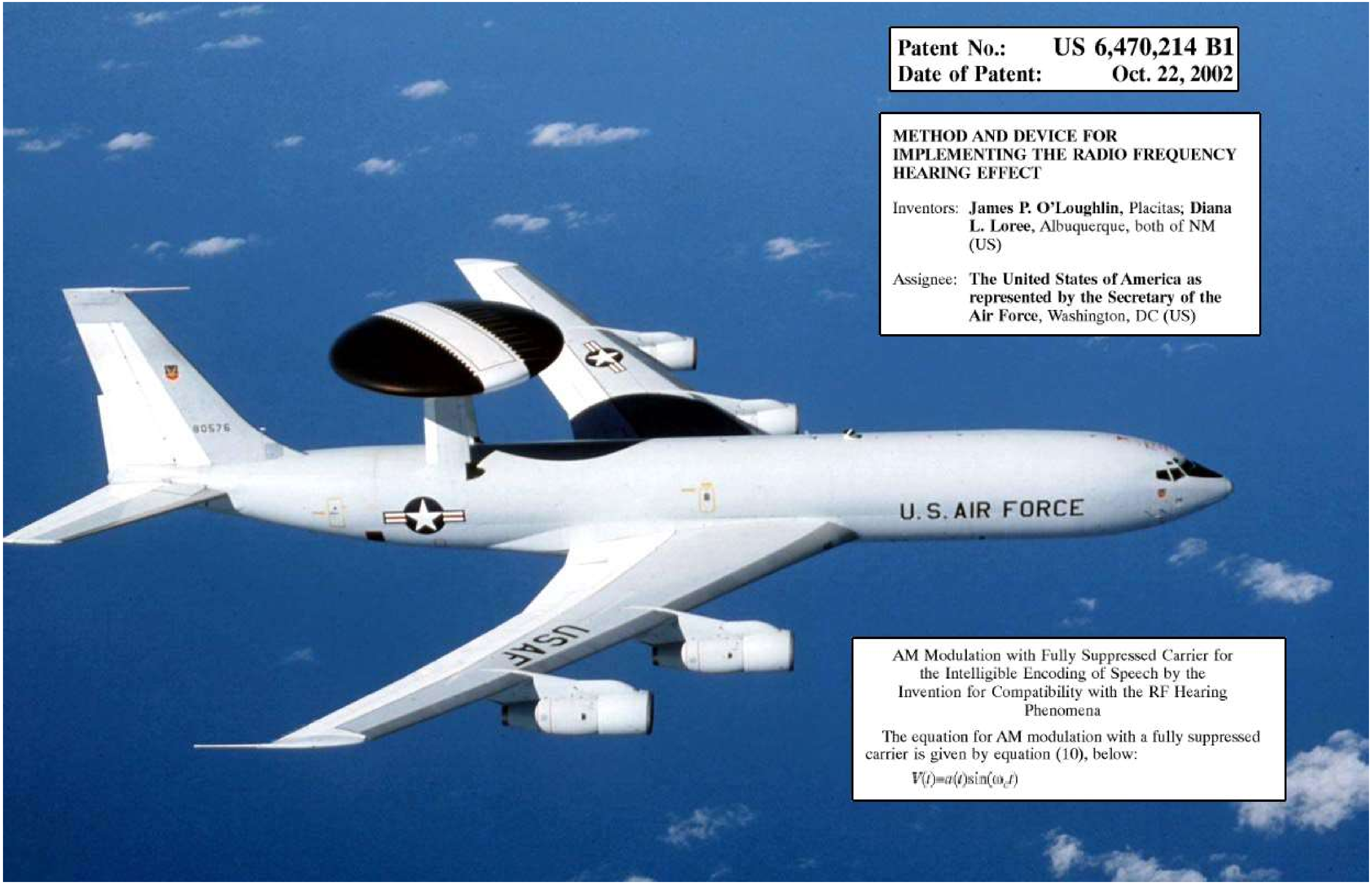
(TS//SI//NF) Most international telephone calls are routed through a small number of switches or "chokepoints" in the international telephone switching system en route to their final destination. The United States is a major crossroads for international switched telephone traffic. For example, in 2003, circuit switches worldwide carried approximately 180 billion minutes of telephone communications. Twenty percent of this amount, over 37 billion minutes, either originated or terminated in the United States, and another thirteen percent, over 23 billion minutes, transited the United States (neither originating nor terminating here). [NSA is authorized under Executive Order 12333 to acquire transiting telephone calls.]

[PART OF VERY SECRET DOCUMENT]

(TS//SI//NF) NSA determined that under the Authorization it could gain access to approximately 81% of the international calls into and out of the United States through three corporate partners: COMPANY A had access to 39%, COMPANY B 28%, and COMPANY C 14%. NSA did not seek assistance from local exchange carriers, because that would have given NSA access primarily to domestic calls.

TOP SECRET//STLW//COMINT/ORCON/NOFORN

OBS. DETTA DOKUMENT ÄR I DENNA PÄRM MER TILL FÖR ATT TILLFÖRA VAD 37 METERS SPIONSATS EG. GÖR.



Patent No.: **US 6,470,214 B1**
Date of Patent: **Oct. 22, 2002**

METHOD AND DEVICE FOR IMPLEMENTING THE RADIO FREQUENCY HEARING EFFECT

Inventors: **James P. O'Loughlin**, Placitas; **Diana L. Loree**, Albuquerque, both of NM (US)

Assignee: **The United States of America as represented by the Secretary of the Air Force**, Washington, DC (US)

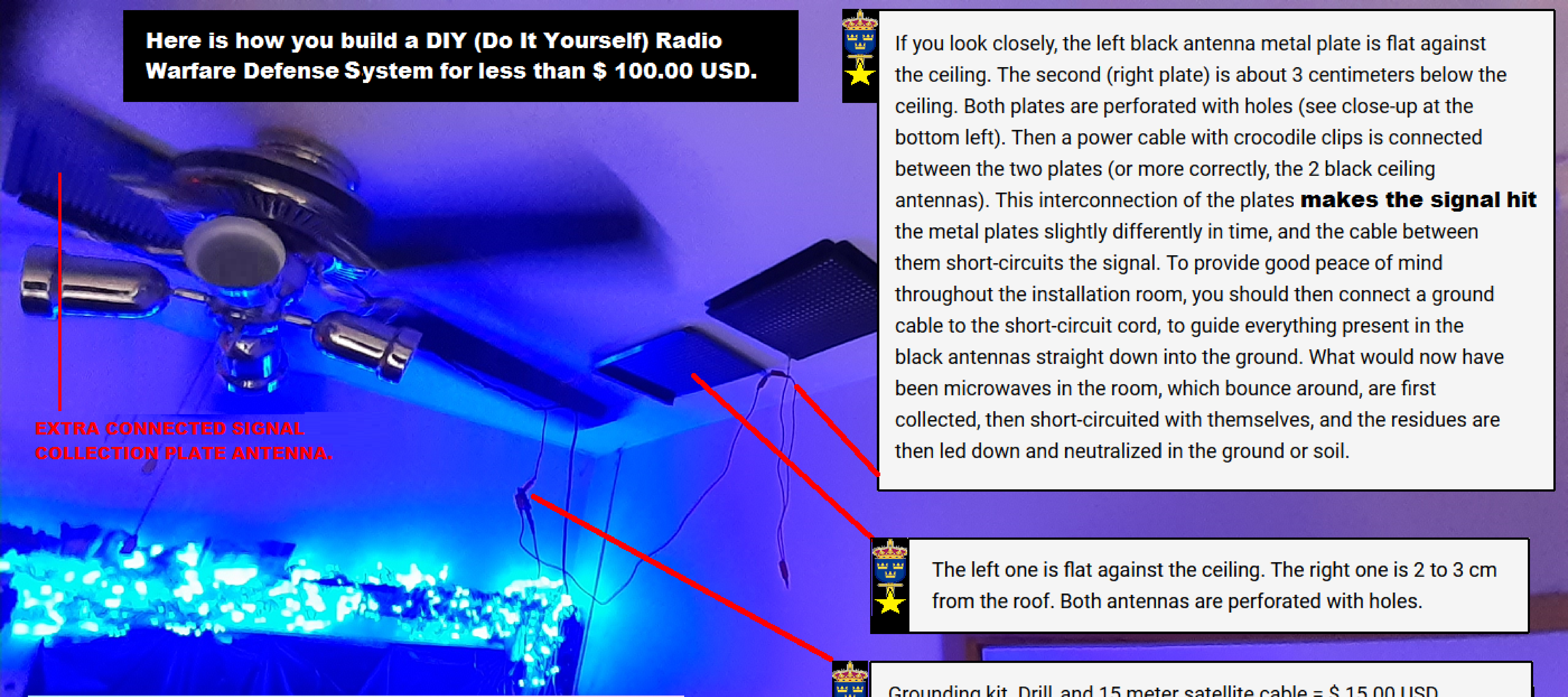
AM Modulation with Fully Suppressed Carrier for the Intelligible Encoding of Speech by the Invention for Compatibility with the RF Hearing Phenomena

The equation for AM modulation with a fully suppressed carrier is given by equation (10), below:

$$V(t)=a(t)\sin(\omega_c t)$$


NO PARKING
Taxis Only

Here is how you build a DIY (Do It Yourself) Radio Warfare Defense System for less than $ 100.00 USD.

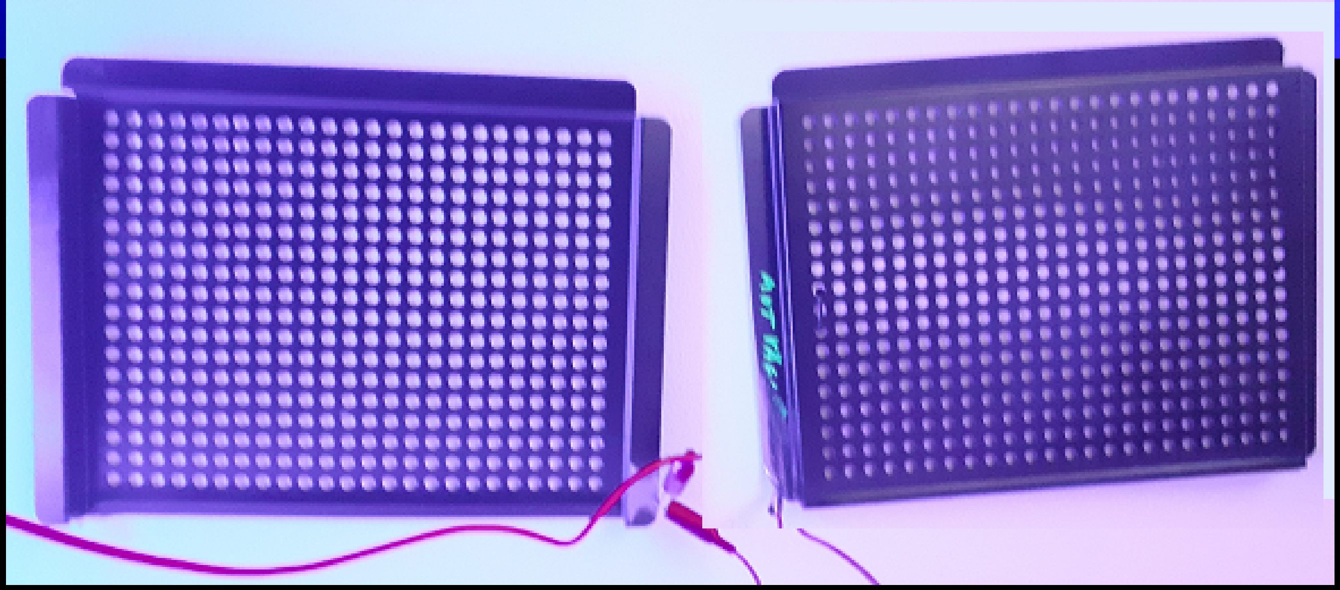


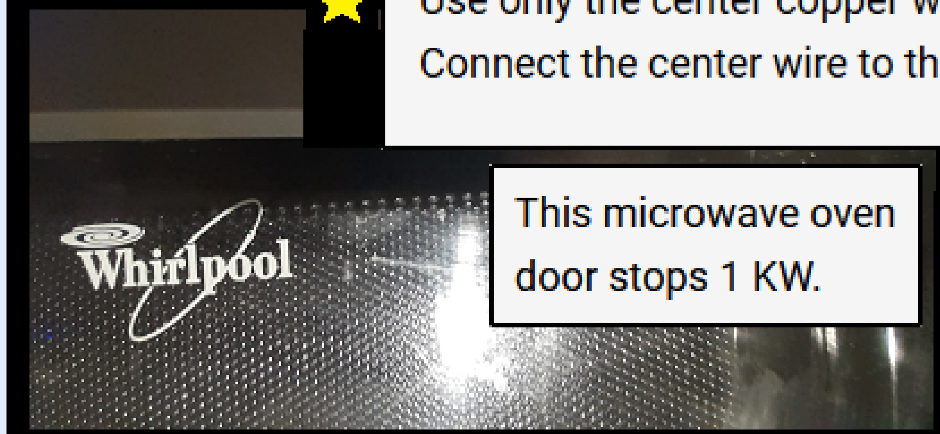
EXTRA CONNECTED SIGNAL COLLECTION PLATE ANTENNA.

If you look closely, the left black antenna metal plate is flat against the ceiling. The second (right plate) is about 3 centimeters below the ceiling. Both plates are perforated with holes (see close-up at the bottom left). Then a power cable with crocodile clips is connected between the two plates (or more correctly, the 2 black ceiling antennas). This interconnection of the plates **makes the signal hit** the metal plates slightly differently in time, and the cable between them short-circuits the signal. To provide good peace of mind throughout the installation room, you should then connect a ground cable to the short-circuit cord, to guide everything present in the black antennas straight down into the ground. What would now have been microwaves in the room, which bounce around, are first collected, then short-circuited with themselves, and the residues are then led down and neutralized in the ground or soil.

The left one is flat against the ceiling. The right one is 2 to 3 cm from the roof. Both antennas are perforated with holes.

Grounding kit. Drill and 15 meter satellite cable = $ 15.00 USD.
Use only the center copper wire. The outer protects the ground wire.
Connect the center wire to the top and hit the drill into the ground.





This microwave oven door stops 1 KW.

MICROWAVE OVEN DOOR WITH NET HOLES.

400 mm DRILL = $ 2.00 USD.

An even more powerful construction can be achieved by applying heavy magnets to the construction. I can show you later.

You can contact me at security.terminal@gustavnorstrom.com - or via telephone - 00 46 073 970 26 00 .
This working prototype can be studied where it is built in Sweden. Heden 132 Bollnäs, 821 31.

<u>— I of course have more advanced systems, but this one is cheap, works and provides relax for your head.</u>

Owner of this Website and Military Contractor: Mr. Gustav Norstrom.
Working on the behalf of the Royal Kingdom of Sweden.

Direct Telephone Number: 00 46 (0) 73 970 26 00.

WE HIJACK AMERICAN AND RUSSIAN SPYSATELLITES WITH MAGNETRON SHOOTERS - BECAUSE WE ARE TIRED OF HEARING IN OUR HEADS THAT "WE ARE NOT GOD" - 50 TIMES PER DAY.

/ The people of Scandinavia.

https://militaryhighcommand.com ★

PASS
PASSPORT
PASSEPORT

SVERIGE **SWEDEN** **SUÈDE**

Typ/ *Type*
P

Kod/ *Code*
SWE

Passnr./ *Passport No.*
AA2793436

1. Efternamn/ *Surname*
NORSTRÖM

2. Förnamn/ *Given names*
PER GUSTAV OLOF

3. Nationalitet/ *Nationality*
SVENSK/ SWEDISH

3a. Personnr./ *Personal Id. No.*
740621-1750

4. Födelsedatum/ *Date of birth*
21 JUN/JUN 74

4a. Längd/ *Height*
185 CM

5. Kön/ *Sex*
M/M

6. Utfärdat datum/ *Date of issue*
08 DEC/DEC 22

7. Sista giltighetsdag/ *Date of expiry*
08 DEC/DEC 27

8. Födelseort/ *Place of birt*
KLOSTER

CAN
101809

9. Myndighet/ *Authority*