RADIATION PATTERNS

The radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. Antenna radiation patterns are taken at one frequency, one polarization, and one plane cut. The patterns are usually presented in polar or rectilinear form with a dB strength scale. Patterns are normalized to the maximum graph value, 0 dB, and a directivity is given for the antenna. This means that if the side lobe level from the radiation pattern were down -13 dB, and the directivity of the antenna was 4 dB, then the sidelobe gain would be -9 dB.

Figures 1 to 14 on the pages following depict various antenna types and their associated characteristics. The patterns depicted are those which most closely match the purpose for which the given shape was intended. In other words, the radiation pattern can change dramatically depending upon frequency, and the wavelength to antenna characteristic length ratio. See section 3-4. Antennas are designed for a particular frequency. Usually the characteristic length is a multiple of $\lambda/2$ minus 2-15% depending on specific antenna characteristics.

The gain is assumed to mean directional gain of the antenna compared to an isotropic radiator transmitting to or receiving from all directions.

The half-power (-3 dB) beamwidth is a measure of the directivity of the antenna.

Polarization, which is the direction of the electric (not magnetic) field of an antenna is another important antenna characteristic. This may be a consideration for optimizing reception or jamming.

The bandwidth is a measure of how much the frequency can be varied while still obtaining an acceptable VSWR (2:1 or less) and minimizing losses in unwanted directions. See Glossary, Section 10.

A 2:1 VSWR corresponds to a 9.5dB (or 10%) return loss - see Section 6-2.

Two methods for computing antenna bandwidth are used:

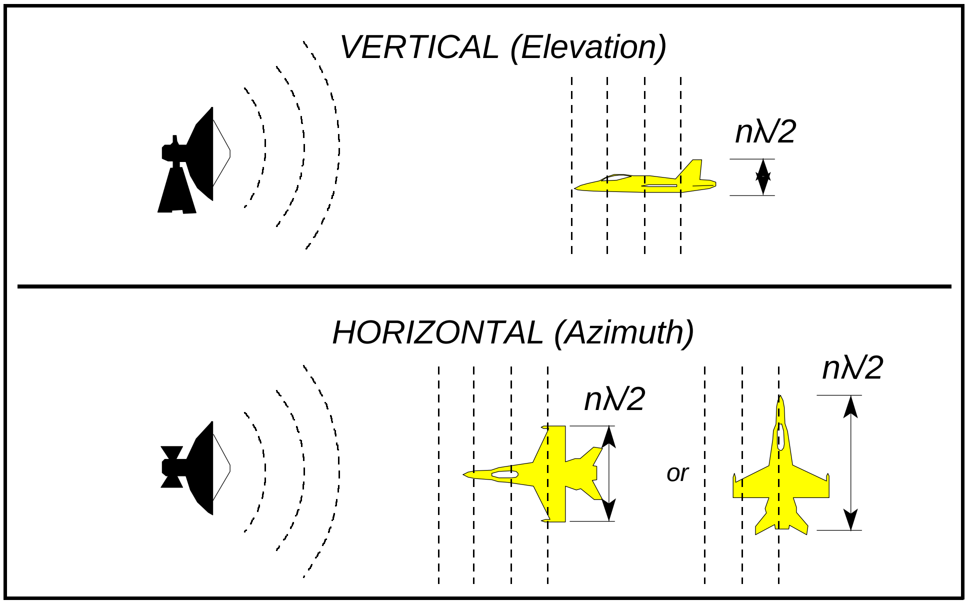
Narrowband by %, $B = \left(\frac{F_U - F_L}{F_C}\right)(100)$, where F_C = Center frequency

Broadband by ratio, $B = \frac{F_U}{F_L}$

An antenna is considered broadband if $F_U / F_L > 2$. The table at the right shows the equivalency of the two, however the shaded values are not normally used because of the aforementioned difference in broadband/narrowband.

Bandwidth	
%	Ratio
5	1.05 : 1
10	1.11 : 1
20	1.22 : 1
30	1.35 : 1
40	1.50 : 1
50	1.67 : 1
60	1.85 : 1
67	2 : 1
100	3 : 1
120	4 : 1
133	5 : 1
150	7 : 1
160	9 : 1
163	10 : 1

For an object that experiences a plane wave, the resonant mode is achieved when the dimension of the object is $n\lambda/2$, where n is an integer. Therefore, one can treat the apertures shown in the figure below as half wave length dipole antennas for receiving and reflecting signals. More details are contained in section 8-4.



The following lists antenna types by page number. The referenced page shows frequency limits, polarizations, etc.

Type	Page	Type	Page
4 arm conical spiral	3-3.6	log periodic	3-3.8
alford loop	3-3.4	loop, circular	3-3.4
aperture synthesis	3-3.8	loop, alfred	3-3.4
array	3-3.8	loop, square	3-3.4
axial mode helix	3-3.5	luneberg lens	3-3.9
biconical w/polarizer	3-3.6	microstrip patch	3-3.9
biconical	3-3.6	monopole	3-3.3
cavity backed circuit fed slot	3-3.9	normal mode helix	3-3.5
cavity backed spiral	3-3.5	parabolic	3-3.7
circular loop	3-3.4	patch	3-3.9
conical spiral	3-3.5	reflector	3-3.9
corner reflector	3-3.9	rhombic	3-3.3
dipole array, linear	3-3.8	sinuous, dual polarized	3-3.6
dipole	3-3.3	slot, guide fed	3-3.9
discone	3-3.4	slot, cavity backed	3-3.9
dual polarized sinuous	3-3.6	spiral, 4 arm conical	3-3.6
guide fed slot	3-3.9	spiral, conical	3-3.5
helix, normal mode	3-3.5	spiral, cavity backed	3-3.5
helix, axial mode	3-3.5	square loop	3-3.4
horn	3-3.7	vee	3-3.3
linear dipole array	3-3.8	yagi	3-3.8

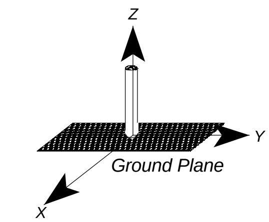
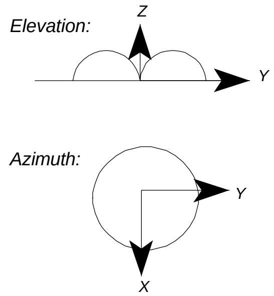
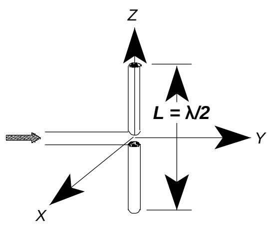
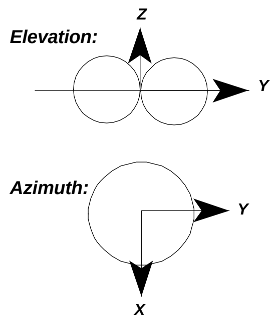
Antenna Type	Radiation Pattern	Characteristics
MONOPOLE 		***Polarization: Linear*** *Vertical as shown* ***Typical Half-Power Beamwidth*** *45 deg x 360 deg* ***Typical Gain:*** *2-6 dB at best* ***Bandwidth:*** *10% or 1.1:1* ***Frequency Limit*** ***Lower:*** *None* ***Upper:*** *None* ***Remarks:*** *Polarization changes to horizontal if rotated to horizontal*
λ/2 DIPOLE 		***Polarization****: Linear* *Vertical as shown* ***Typical Half-Power Beamwidth*** *80 deg x 360 deg* ***Typical Gain:*** *2 dB* ***Bandwidth:*** *10% or 1.1:1* ***Frequency Limit*** ***Lower:*** *None* ***Upper:*** *8 GHz (practical limit)* ***Remarks:*** *Pattern and lobing changes significantly with L/f. Used as a gain reference < 2 GHz.*

Figure 1

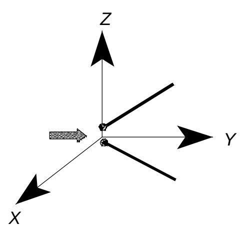
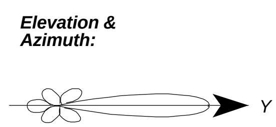
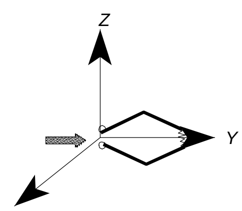
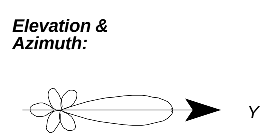
Antenna Type	Radiation Pattern	Characteristics
VEE 		***Polarization****: Linear* *Vertical as shown* ***Typical Half-Power Beamwidth*** *60 deg x 60 deg* ***Typical Gain:*** *2 to 7 dB* ***Bandwidth:*** *"Broadband"* ***Frequency Limit*** ***Lower:*** *3 MHz* ***Upper:*** *500 MHz (practical limits)* ***Remarks:*** *24KHz versions are known to exist. Terminations may be used to reduce backlobes.*
RHOMBIC 		***Polarization****: Linear* *Vertical as shown* ***Typical Half-Power Beamwidth*** *60 deg x 60 deg* ***Typical Gain:*** *3 dB* ***Bandwidth:*** *"Broadband"* ***Frequency Limit*** ***Lower:*** *3 MHz* ***Upper:*** *500 MHz* ***Remarks:*** *Termination resistance used to reduce backlobes.*

Figure 2

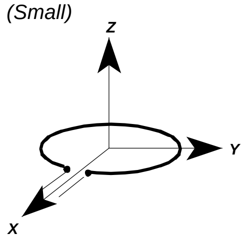
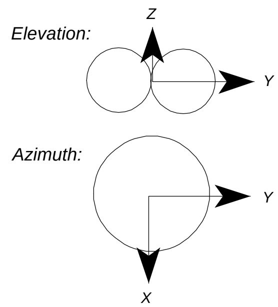
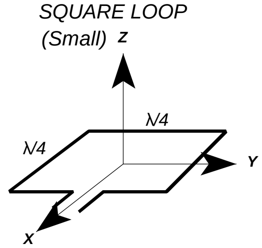
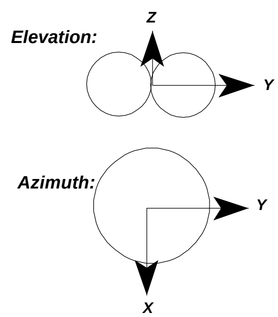
Antenna Type	Radiation Pattern	Characteristics
CIRCULAR LOOP (Small) 		***Polarization:*** *Linear Horizontal as shown* ***Typical Half-Power Beamwidth:*** *80 deg x 360 deg* ***Typical Gain:*** *-2 to 2 dB* ***Bandwidth:*** *10% or 1.1:1* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *1 GHz*
SQUARE LOOP (Small) 		***Polarization:*** *Linear Horizontal as shown* ***Typical Half-Power Beamwidth:*** *100 deg x 360 deg* ***Typical Gain:*** *1-3 dB* ***Bandwidth:*** *10% or 1.1:1* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *1 GHz*

Figure 3

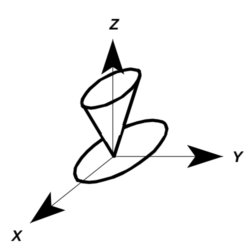
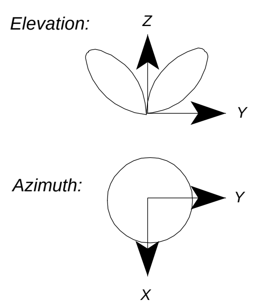
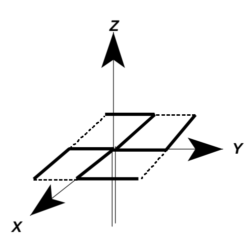
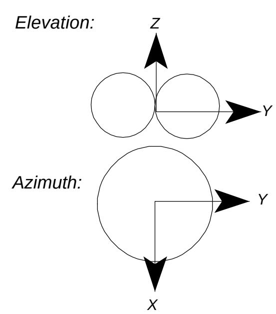
Antenna Type	Radiation Pattern	Characteristics
DISCONE 		***Polarization:*** *Linear Vertical as shown* ***Typical Half-Power Beamwidth:*** *20-80 deg x 360 deg* ***Typical Gain:*** *0-4 dB* ***Bandwidth:*** *100% or 3:1* ***Frequency Limit:*** ***Lower:*** *30 MHz* ***Upper:*** *3 GHz*
ALFORD LOOP 		***Polarization:*** *Linear Horizontal as shown* ***Typical Half-Power Beamwidth:*** *80 deg x 360 deg* ***Typical Gain:*** *-1 dB* ***Bandwidth:*** *67% or 2:1* ***Frequency Limit:*** ***Lower:*** *100 MHz* ***Upper:*** *12 GHz*

Figure 4

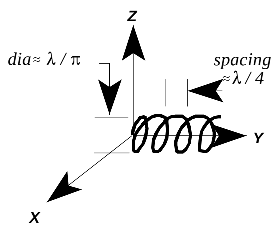
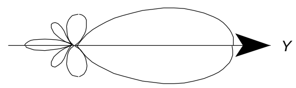
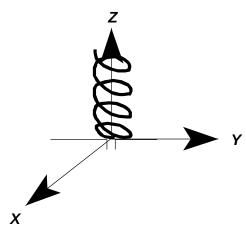
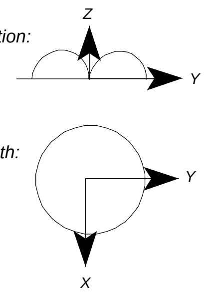
Antenna Type	Radiation Pattern	Characteristics
AXIAL MODE HELIX  	 	***Polarization:*** *Circular* *Left hand as shown* ***Typical Half-Power Beamwidth:*** *50 deg x 50 deg* ***Typical Gain:*** *10 dB* ***Bandwidth:*** *52% or 1.7:1* ***Frequency Limit*** ***Lower:*** *100 MHz* ***Upper:*** *3 GHz* ***Remarks:*** *Number of loops >3*
NORMAL MODE HELIX  	 	***Polarization:*** *Circular - with an ideal pitch to diameter ratio.* ***Typical Half-Power Beamwidth:*** *60 deg x 360 deg* ***Typical Gain:*** *0 dB* ***Bandwidth:*** *5% or 1.05:1* ***Frequency Limit*** ***Lower:*** *100 MHz* ***Upper:*** *3 GHz*

Figure 5

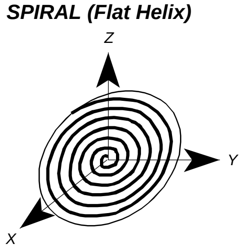
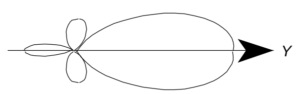
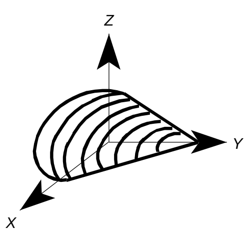
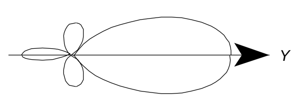
Antenna Type	Radiation Pattern	Characteristics
CAVITY BACKED SPIRAL (Flat Helix)  	 	***Polarization:*** *Circular* *Left hand as shown* ***Typical Half-Power Beamwidth:*** *60 deg x 90 deg* ***Typical Gain:*** *2-4 dB* ***Bandwidth:*** *160% or 9:1* ***Frequency Limit:*** ***Lower:*** *500 MHz* ***Upper:*** *18 GHz*
CONICAL SPIRAL  	 	***Polarization:*** *Circular* *Left hand as shown* ***Typical Half-Power Beamwidth:*** *60 deg x 60 deg* ***Typical Gain:*** *5-8 dB* ***Bandwidth:*** *120% or 4:1* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *18 GHz*

Figure 6

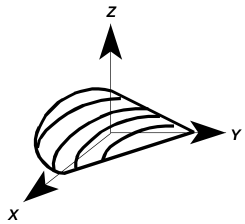
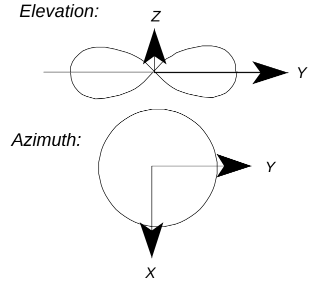
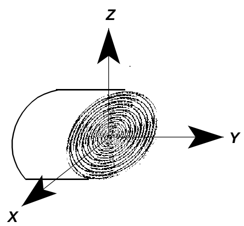
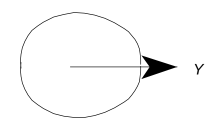
Antenna Type	Radiation Pattern	Characteristics
4 ARM CONICAL SPIRAL 		***Polarization:*** *Circular Left hand as shown* ***Typical Half-Power Beamwidth:*** *50 deg x 360 deg* ***Typical Gain:*** *0 dB* ***Bandwidth:*** *120% or 4:1* ***Frequency Limit:*** ***Lower:*** *500 MHz* ***Upper:*** *18 GHz*
DUAL POLARIZED SINUOUS 	***Elevation & Azimuth*** 	***Polarization****: Dual vertical or horizontal or dual Circular right hand or left hand with hybrid* ***Typical Half-Power Beamwidth:*** *75 deg x 75 deg* ***Typical Gain:*** *2 dB* ***Bandwidth:*** *163% or 10:1* ***Frequency Limit:*** ***Lower:*** *500 MHz* ***Upper:*** *18 GHz*

Figure 7

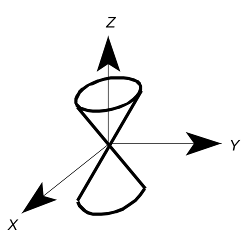
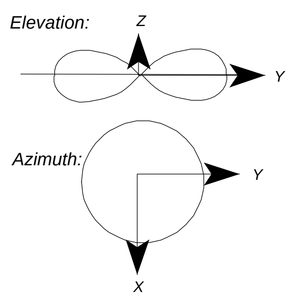
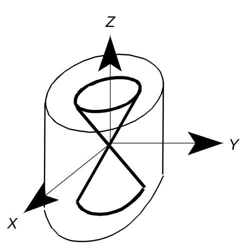
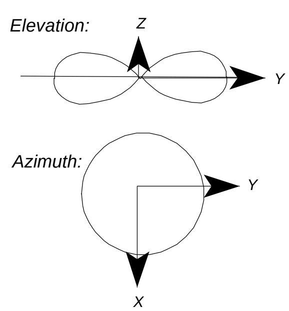
Antenna Type	Radiation Pattern	Characteristics
BICONICAL 		***Polarization:*** *Linear, Vertical as shown* ***Typical Half-Power Beamwidth:*** *20-100 deg x 360 deg* ***Typical Gain:*** *0-4 dB* ***Bandwidth:*** *120% or 4:1* ***Frequency Limit:*** ***Lower:*** *500 MHz* ***Upper:*** *40 GHz*
BICONICAL W/POLARIZER 		***Polarization:*** *Circular, Direction depends on polarization* ***Typical Half-Power Beamwidth:*** *20-100 deg x 360 deg* ***Typical Gain:*** *-3 to 1 dB* ***Bandwidth:*** *100% or 3:1* ***Frequency Limit:*** ***Lower:*** *2 GHz* ***Upper:*** *18 GHz*

Figure 8

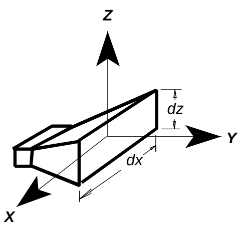
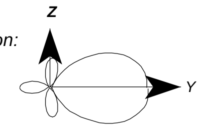
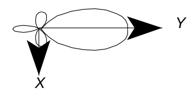
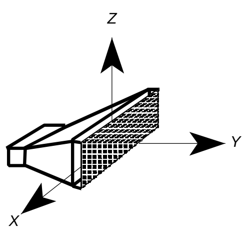
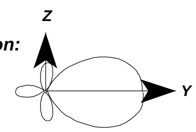
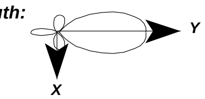
Antenna Type	Radiation Pattern	Characteristics
HORN 	Elevation:  3 dB beamwidth = 56 λ°/dz Azimuth:  3 dB beamwidth = 70 λ°/dx	***Polarization:*** *Linear* ***Typical Half-Power Beamwidth:*** *40 deg x 40 deg* ***Typical Gain:*** *5 to 20 dB* ***Bandwidth:*** *If ridged: 120% or 4:1* *If not ridged: 67% or 2:1* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *40 GHz*
HORN W / POLARIZER 	***Elevation:***  ***Azimuth:*** 	***Polarization:*** *Circular, Depends on polarizer* ***Typical Half-Power Beamwidth:*** *40 deg x 40 deg* ***Typical Gain:*** *5 to 10 dB* ***Bandwidth:*** *60% or 2:1* ***Frequency Limit:*** ***Lower:*** *2 GHz* ***Upper:*** *18 GHz*

Figure 9

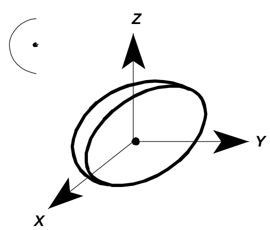
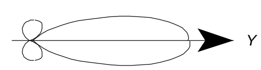
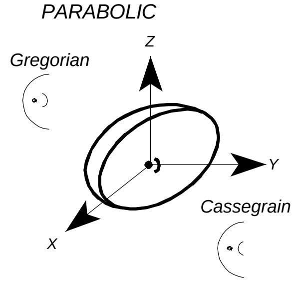
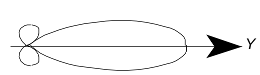
Antenna Type	Radiation Pattern	Characteristics
PARABOLIC (Prime) 	***Elevation & Azimuth*** 	***Polarization:*** *Takes polarization of feed* ***Typical Half-Power Beamwidth:*** *1 to 10 deg* ***Typical Gain:*** *20 to 30 dB* ***Bandwidth:*** *33% or 1.4:1 limited mostly by feed* ***Frequency Limit:*** ***Lower:*** *400 MHz* ***Upper:*** *13+ GHz*
PARABOLIC 	*Elevation & Azimuth* 	***Polarization:*** *Takes polarization of feed* ***Typical Half-Power Beamwidth:*** *1 to 10 deg* ***Typical Gain:*** *20 to 30 dB* ***Bandwidth:*** *33% or 1.4:1* ***Frequency Limit:*** ***Lower:*** *400 MHz* ***Upper:*** *13+ GHz*

Figure 10

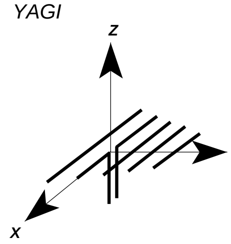
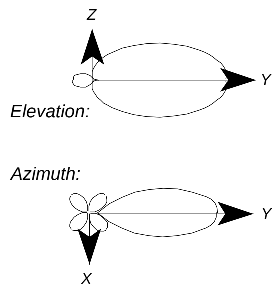
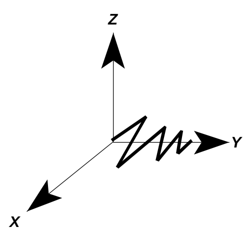
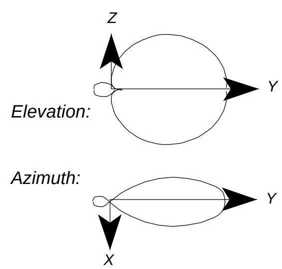
Antenna Type	Radiation Pattern	Characteristics
YAGI 		***Polarization:*** *Linear* *Horizontal as shown* ***Typical Half-Power Beamwidth*** *50 deg X 50 deg* ***Typical Gain:*** *5 to 15 dB* ***Bandwidth:*** *5% or 1.05:1* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *2 GHz*
LOG PERIODIC 		***Polarization:*** *Linear* ***Typical Half-Power Beamwidth:*** *60 deg x 80 deg* ***Typical Gain:*** *6 to 8 dB* ***Bandwidth:*** *163% or 10:1* ***Frequency Limit:*** ***Lower:*** *3 MHz* ***Upper:*** *18 GHz* ***Remarks:*** *This array may be formed with many shapes including dipoles or toothed arrays.*

Figure 11

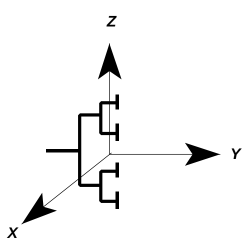
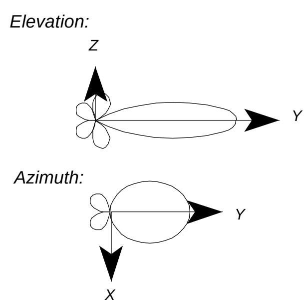
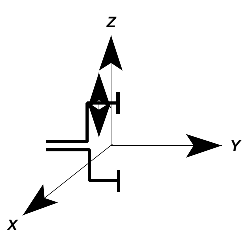
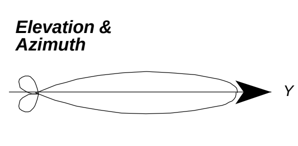
Antenna Type	Radiation Pattern	Characteristics
LINEAR DIPOLE ARRAY (Corporate Feed) 		***Polarization:*** *Element dependent* *Vertical as shown* ***Typical Half-Power Beamwidth:*** *Related to gain* ***Typical Gain:*** *Dependent on number of elements* ***Bandwidth:*** *Narrow* ***Frequency Limit:*** ***Lower:*** *10 MHz* ***Upper:*** *10 GHz*
APERTURE SYNTHESIS 		*All characteristics dependent on elements* ***Remarks:*** *Excellent side-looking, ground mapping where the aircraft is a moving linear element.*

Figure 12

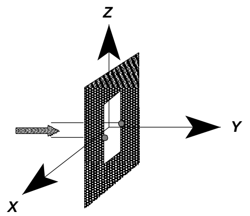
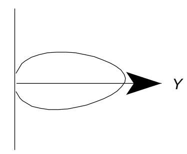
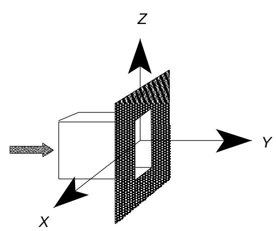
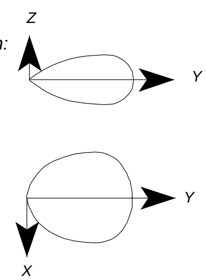
Antenna Type	Radiation Pattern	Characteristics
CAVITY BACKED CIRCUIT FED SLOT (and Microstrip Patch) 	***Elevation & Azimuth*** 	***Polarization:*** *Linear, vertical as shown* ***Typical Half-Power Beamwidth**: 80 deg x 80 deg* ***Typical Gain:*** *6 dB* ***Bandwidth:*** *Narrow* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *18 GHz* ***Remarks:*** *The feed line is sometimes separated from the radiator by a dialetric & uses capacititive coupling. Large conformal phased arrays can be made this way.*
GUIDE FED SLOT 	*Elevation:* *Azimuth:* 	***Polarization:*** *Linear,* ***Typical Half-Power Beamwidth*** *Elevation: 45-50°* *Azimuth: 80°* ***Typical Gain:*** *0 dB* ***Bandwidth:*** *Narrow* ***Frequency Limit:*** ***Lower:*** *2 GHz* ***Upper:*** *40 GHz* ***Remarks:*** *Open RF Waveguide*

Figure 13

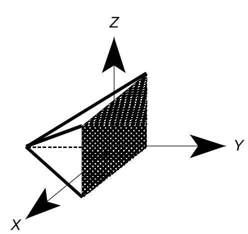
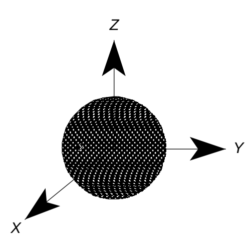
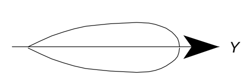
Antenna Type	Radiation Pattern	Characteristics
CORNER REFLECTOR 	*Elevation: (Z-Y)* *Azimuth: (X-Y)* *Dependent upon feed emitter*	***Polarization**: Feed dependent* ***Typical Half-Power Beamwidth*** *40 deg x variable* ***Typical Gain:*** *10 dB above feed* ***Bandwidth:*** *Narrow* ***Frequency Limit*** ***Lower:*** *1 GHz* ***Upper:*** *40 GHz* ***Remarks:*** *Typically fed with a dipole or colinear array.*
LUNEBURG LENS 	*Elevation & Azimuth* 	***Polarization:*** *Feed dependent* ***Typical Half-Power Beamwidth:*** *System dependent* ***Typical Gain:*** *System dependent* ***Bandwidth:*** *Narrow* ***Frequency Limit*** ***Lower:*** *1 GHz* ***Upper:*** *40 GHz* ***Remarks:*** *Variable index dielectric sphere.*

Figure 14