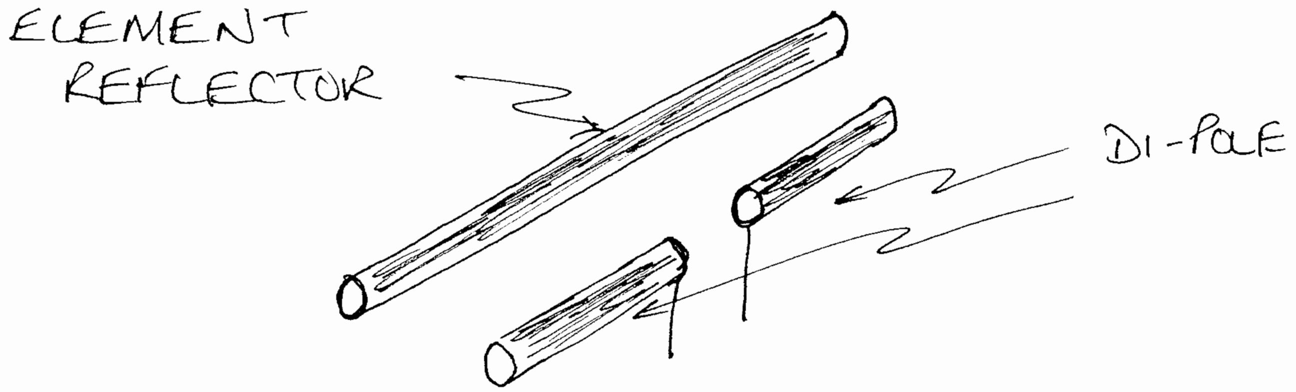
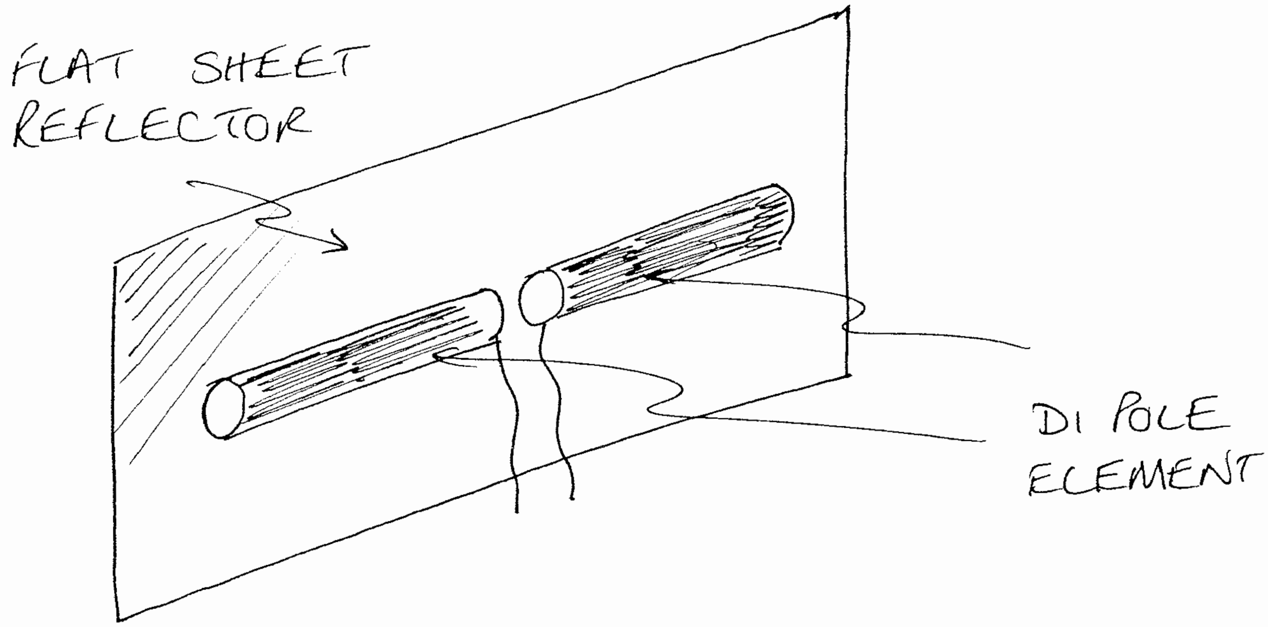
REFLECTOR ANTENNAS

AT HIGHER MICROWAVE FREQUENCIES REFLECTORS ARE OFTEN USED TO MODIFY THE RADIATION PATTERN OF AN ANTENNA

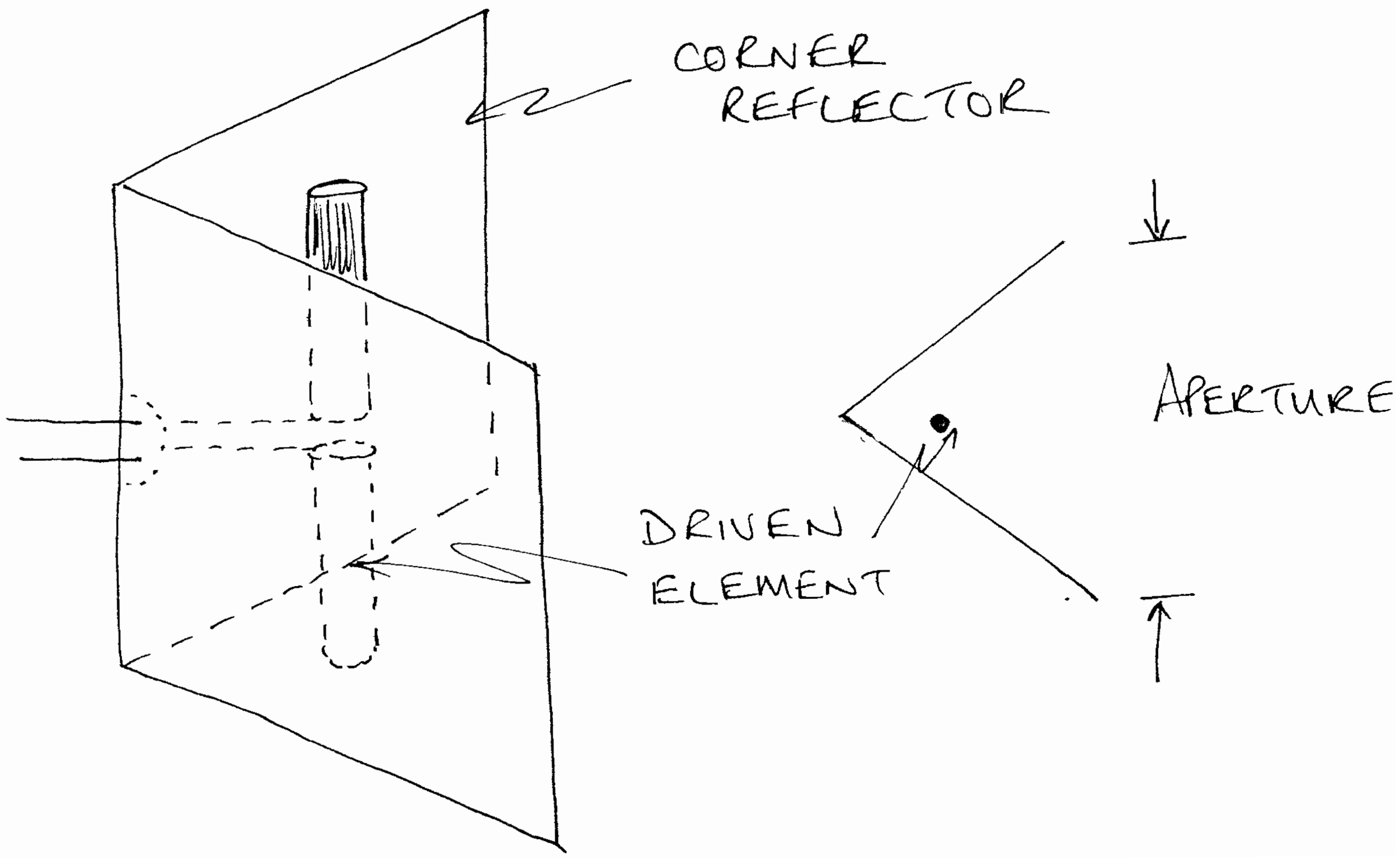
THE SIMPLEST FORM OF REFLECTOR IS THE ELEMENT REFLECTOR (AS USED IN THE YAGI ARRAY - MORE LATER)



THE ELEMENT REFLECTOR IS VERY SENSITIVE TO SMALL FREQUENCY CHANGES AND HENCE AT HIGHER FREQUENCIES MAY BE REPLACED BY THE CORRESPONDINGLY INSENSITIVE FLAT SHEET TO PRODUCE GREATER BANDWIDTHS AND A GAIN OF ABOUT 9 dBi



WITH TWO FLAT SHEETS INTERSECTING AT AN ANGLE THE CORNER REFLECTOR IS FORMED WHICH HAS A SHARPER RADIATION PATTERN, GREATER APERTURE AREA AND HENCE A GAIN OF UP TO 15dBi



WHEN IT IS CONVENIENT TO BUILD ANTENNAS WITH APERTURES OF MANY WAVELENGTHS, PARABOLIC REFLECTORS CAN BE USED TO PROVIDE HIGHLY DIRECTIVE ANTENNAS WITH HIGH GAIN.

PARABOLOIDAL ANTENNAS

THE DIMENSIONS OF THE RADIATING SURFACES OF MANY PARABOLIC ANTENNAS ARE LARGE COMPARED TO THE WAVELENGTH USED AND THEY BEHAVE IN SOME WAYS AS REFLECTING MIRRORS DO AT OPTICAL FREQUENCIES.

HENCE, GEOMETRICAL OPTICS WHICH IS BASED UPON RAYS AND WAVEFRONTS MAY BE USED TO STUDY CERTAIN ASPECTS OF THESE ANTENNAS.

GENERAL PROPERTIES OF REFLECTOR SYSTEMS CAN BE STUDIED USING SIMPLE RAY-OPTICS WHILE SOME SPECIAL PROPERTIES REQUIRE THE USE OF E-M FIELD THEORY AND DIFFRACTION THEORY.

THE PARABOLOIDAL ANTENNA IS SUCH A UBIQUITOUS ANTENNA SYSTEM THAT IT MERITS FURTHER TREATMENT.

PARABOLOIDAL ANTENNAS ARE OF COURSE USED IN TERRESTRIAL AND SATELLITE TELECOMMUNICATIONS, IN RADAR AND IN RADIO ASTRONOMY. MANY OTHER SHAPES OF REFLECTORS HAVE BEEN USED (FOR EXAMPLE HYPERBOLIC AND ELLIPTICAL), BUT THE PARABOLIC SHAPE IS PREFERRED DUE TO ITS PARALLEL BEAM AND HIGH DIRECTIVITY.

ALL PARABOLIC ANTENNAS ARE TAKEN AS A SECTION FROM A PARABOLOID, THOUGH THERE ARE MANY WAYS IN WHICH THIS CAN BE DONE. COMMONLY THE APERTURE IS CIRCULAR, IN APPLICATIONS WHERE A SYMMETRICAL BEAM IS APPROPRIATE.

EXAMPLES OF NON-CIRCULAR APERTURE PARABOLOIDS ARE SEEN IN RADAR SUSTEMS, WHERE OFTEN A HIGH RESOLUTION IN AZIMUTH IS REQUIRED BUT NOT IN ELEVATION.

THE PARABOLOIDAL ANTENNA IS OF COURSE A <u>SECONDARY</u> ANTENNA IN THAT IT MUST BE DRIVEN BY A <u>PRIMARY FEED</u> ANTENNA. THE CHARACTERISTICS OF THE FEED ANTENNA DETERMINE THE FIELD DISTRIBUTION OF THE ENTIRE ANTENNA <u>SUSTEM</u>

PROPERTIES OF THE PARABOLOIDAL GEOMETRY

A PARABOLIC SURFACE HAS THE USEFUL PROPERTY OF BEING ABLE TO CONVERT A DIVERGING SPHERICAL WAVEFRONT INTO A PARALLEL PLANE WAVEFRONT, THEREBY PRODUCING A HIGHLY FOCUSSED OR NARROW PENCIL BEAM.

THIS PROPERTY OF FOCUSSING WHICH IS USUALLY ASSOCIATED WITH LIGHT RAYS, MIRRORS AND LENSES CAN BE EQUALLY APPLIED TO PARABOLIC REFLECTORS AT MICROWAVE FREQUENCIES.

A PARABOLIC SURFACE WHICH IS OBTAINED BY ROTATING A PARABOLIC CURVE ON ITS AXIS SATISFIES THE EQUATION;

$$y^2 = 4fx$$

WHERE y IS ANY ORDINATE ON THE SURFACE, f IS THE FOCAL LENGTH AND x IS THE CORRESONDING ABSCISSA. (SEE LAST PAGE OF PREVIOUS LECTURE)

WE CAN ALSO USE POLAR COORDINATES;

$$r = f\sec^2(\psi/2)$$

THE ESSENTIAL FEATURE OF THE PARABOLIC GEOMETRY IS THE FOCUSSING PROPERTY;

ALL THE RAYS LEAVING THE FOCAL POINT F AFTER REFLECTION FROM THE SURFACE EMERGE PARALLEL TO ONE ANOTHER AND REACH THE PLANE YY' AT THE SAME TIME - SO FORMING AN EQUIPHASE WAVEFRONT.

HENCE, WE HAVE;

$$FP + PQ = FP' + P'Q' = \text{CONSTANT.}$$

FOR ALL POINTS ON THE SURFACE

THE PARABOLOIDAL SURFACE HAS THE PROPERTY OF CONVERTING SPHERICAL WAVES FROM AN ISOTROPIC SOURCE AT THE FOCUS TO A UNIFORM PLANE WAVE AT THE APERTURE.

FOR A PARTICULAR DIAMETER DISH, THE REFLECTED WAVE HAS A UNIFORM PHASE DISTRIBUTION, BUT A TAPERED AMPLITUDE ONE FOR A GIVEN PRIMARY (FEED) PATTERN. TO OBTAIN A MORE UNIFORM DISTRIBUTION IT IS NECESSARY TO INCREASE THE FOCAL LENGTH f, WHILE KEEPING THE DIAMETER D, CONSTANT (USE A SHALLOWER DISH)

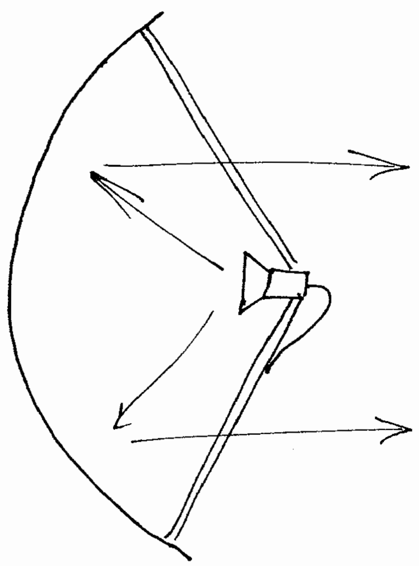
FEED CONFIGURATIONS

THERE ARE A NUMBER OF OPTIONS FOR POSITIONING THE PRIMARY ANTENNA IN RELATION TO THE MAIN REFLECTOR.

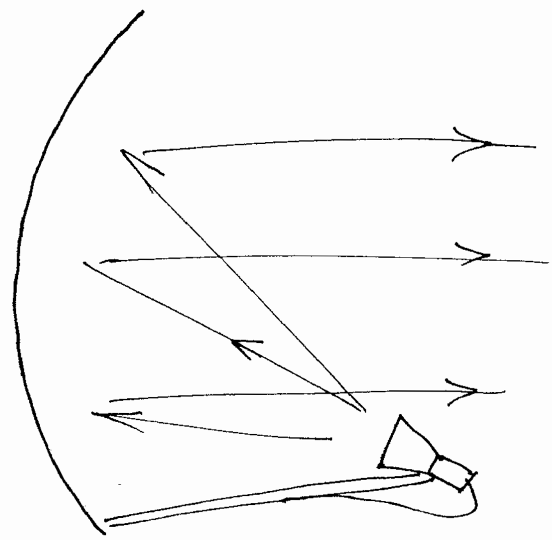
THESE INCLUDE;

* NEWTONIAN, "FRONT FED" SYSTEMS
* CASSEGRAINIAN, HYPERBOLIDAL SUB-REFLECTOR
* GREGORIAN, ELLIPSOIDAL SUB-REFLECTOR

IN GENERAL ANY OF THESE TYPES MAY BE SYMMETRICAL OR OFFSET (ASYMMETRIC)



SYMMETRICAL



OFFSET

BLOCKAGE

THE STANDARD SYMMETRICAL PARABOLIC REFLECTOR CASSEGRAINIAN SYSTEM IS VERY POPULAR IN PRACTICE BECAUSE IT ALLOWS MINIMUM FEEDER LENGTH TO THE RF EQUIPMENT. THE MAJOR DISADVANTAGE OF THIS CONFIGURATION IS DUE TO BLOCKAGE FROM THE HYPERBOLIC SUB-REFLECTOR AND ITS' SUPPORTING STRUTS (TYPICALLY 3 or 4). THE AMOUNT OF BLOCKAGE BECOMES SEVERE WHEN THE SUB-REFLECTOR IS LARGE COMPARED TO THE MAIN REFLECTOR

TO AVOID BLOCKAGE FROM THE SUB-REFLECTOR OFFSET CASSEGRAINIAN SYSTEMS CAN BE USED. HOWEVER, THE ASYMMETRY CAN HAVE A CONSIDERABLE AFFECT ON SOME ASPECTS OF ANTENNA PERFORMANCE

* INCREASED SIDELOBE LEVELS
* BEAM SQUINT
* POOR CROSS-POLAR PROPERTIES

SPILLOVER

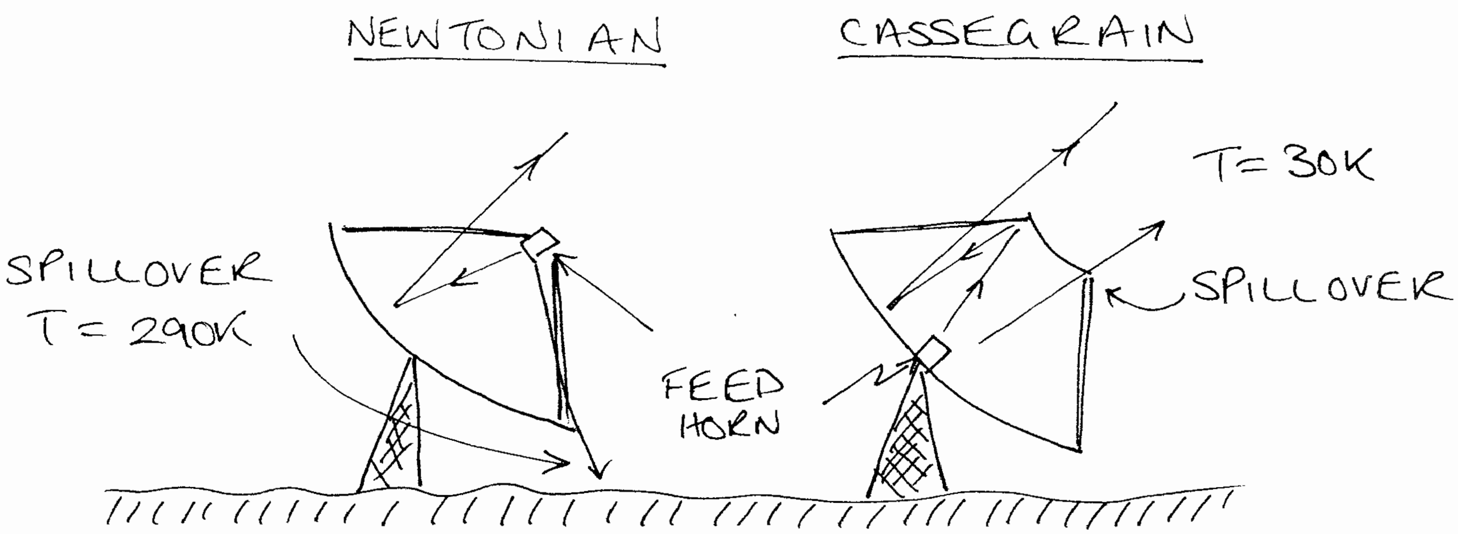
USUALLY THE FOCUS F OF THE PARABOLIC SURFACE IS LOCATED AT THE PLANE YY', AND THE DIAMETER OF THE CIRCULAR APERTURE $D = 4f$ OR $f/D = 0.25$.

MORE GENERALLY THE f/D RATIO TYPICALLY VARIES FROM 0.25 TO 0.5. IF THE f/D RATIO IS TOO LOW THE MAIN REFLECTOR IS POORLY ILLUMINATED AND THE APERTURE EFFICIENCY $\eta_A = 50-60\%$ (POOR). IF f/D IS TOO HIGH ENERGY IS LOST OVER THE RIM OF THE DISH AS SPILLOVER.

SPILLOVER IS A RESULT OF OVER ILLUMINATION, AN CAN CONTRIBUTE TO SIDE AND BACK LOBES VIA DIFFRACTION EFFECTS. TO AVOID SPILLOVER A MICROWAVE ABSORBER IS SOMETIMES USED. THIS IS A LOSSY MATERIAL WHICH HELPS PREVENT EXCESSIVE SIDE-LOBES RADIATING FROM EDGE EFFECTS AND FROM RADIATION FROM SUPPORT STRUTS.

ANTENNA NOISE TEMPERATURE

FOR EARTH STATION SYSTEMS THE CASSEGRAIN ANTENNA HAS A NUMBER OF ADVANTAGES OVER A SIMPLE PARABOLIC REFLECTOR SYSTEM...



ADVANTAGES OF CASSEGRAIN;

* LOWER SPILLOVER PAST PARABOLOIDAL EDGES (TOWARDS WARM EARTH)

* SHORT TRANSMISSION LINES (LOWER NOISE)

* GREATER MECHANICAL STABILITY (SUB-REFLECTOR IS QUITE LIGHT)

DISADVANTAGE OF CASSEGRAIN

* COST

GAIN OF A CIRCULAR APERTURE PARABOLOIDAL REFLECTOR ANTENNA

LET US RECAP ON OUR KNOWLEDGE OF APERTURES; (LECTURE 4)

RADIATION EFFICIENCY;

$$k = \frac{A_e}{A_{em}}$$ ← EFFECTIVE APERTURE (A_e) ; ← MAXIMUM EFFECTIVE APERTURE (A_{em})

APERTURE EFFICIENCY;

$$\eta_A = \frac{A_e}{A_p}$$ ← EFFECTIVE APERTURE (A_e) ; ← PHYSICAL APERTURE (A_p)

WE HAVE;

$$G = kD$$ ← DIRECTIVITY (D) ; GAIN (G)

$$G = kD = k\frac{4\pi A_{em}}{\lambda^2} = k\frac{4\pi}{\lambda^2}\frac{A_e}{k} = \frac{4\pi A_p}{\lambda^2}\eta_A$$

AREA OF A CIRCULAR APERTURE OF DIAMETER D IS;

$$A_p = \pi\left(\frac{D}{2}\right)^2$$

HENCE

$$\boxed{G = \frac{4\pi}{\lambda^2}\eta_A \times \frac{\pi D^2}{4} = \eta_A\left[\frac{\pi D}{\lambda}\right]^2}$$

IF THE SURFACE OF THE REFLECTOR IS NOT PERFECT (BUMPS OR IRREGULARITIES) COMPARED TO THE WAVELENGTH WE FIND;

$$G = \eta_A \left[\frac{\pi D}{\lambda}\right]^2 \exp\left[-(4\pi\epsilon/\lambda)^2\right]$$

ϵ – RMS SURFACE ERROR.

FOR EXAMPLE:

JODRELL BANK #2, 125 x 85 FEET
4 mm SURFACE ERROR

GOONHILLY #1, 85 FEET DIAMETER
2mm SURFACE ERROR

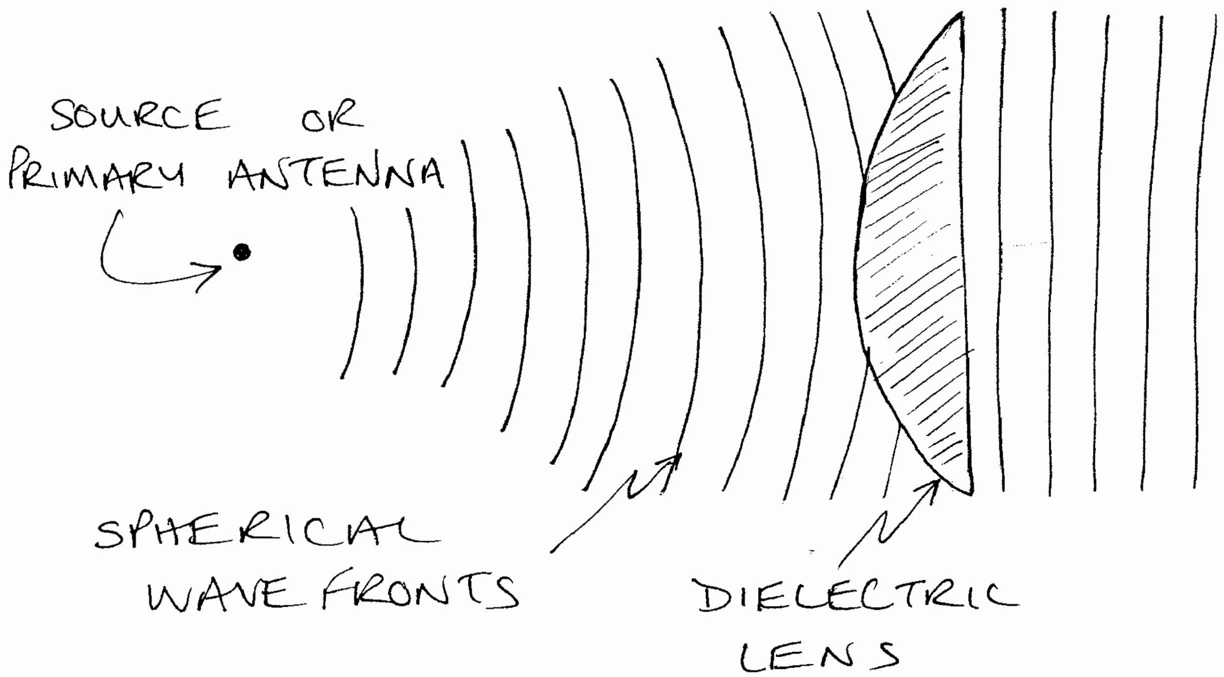
ASSUMING A PRACTICAL PRIMARY FEED DISTRIBUTION (LECTURE 5) WE TYPICALLY FIND THAT

$$\theta_{3dB} \simeq 1.27\lambda/D \quad \text{(RADIANS}$$

WITH $\eta_A \simeq 70\%$ FOR MOST CASES.

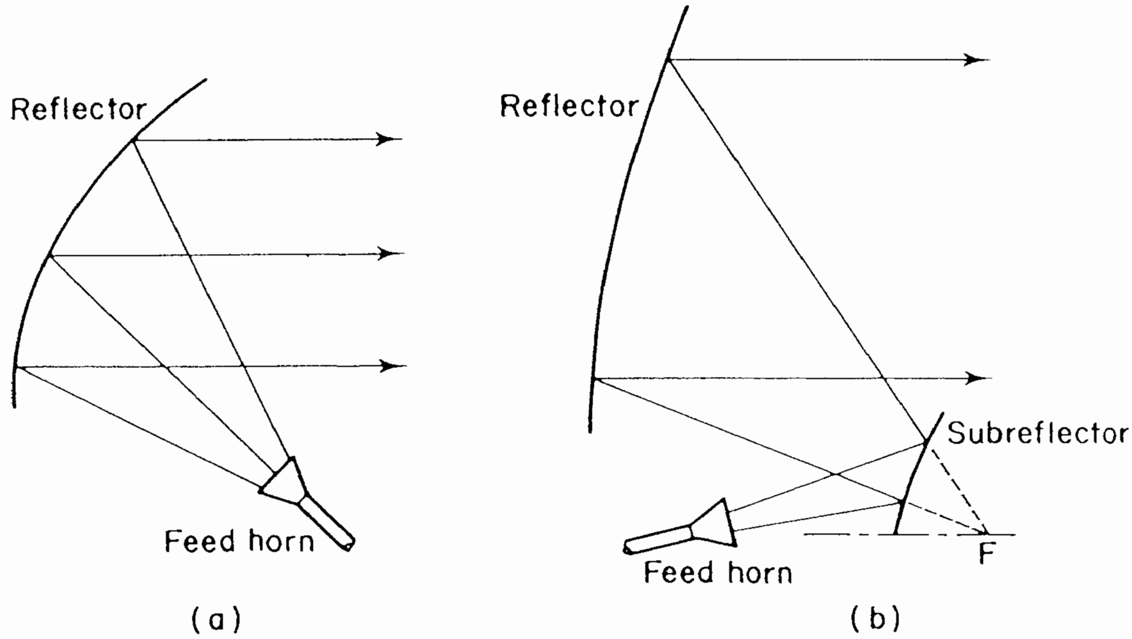
DIELECTRIC LENS ANTENNAS

AT MILLIMETRE WAVELENGTHS LOW-LOSS DIELECTRIC LENS ANTENNAS ARE COMPETITIVE IN TERMS OF WEIGHT AND PERFORMANCE WITH REFLECTOR ANTENNAS – OFTEN CALLED GAUSSIAN OPTICS LENS ANTENNAS



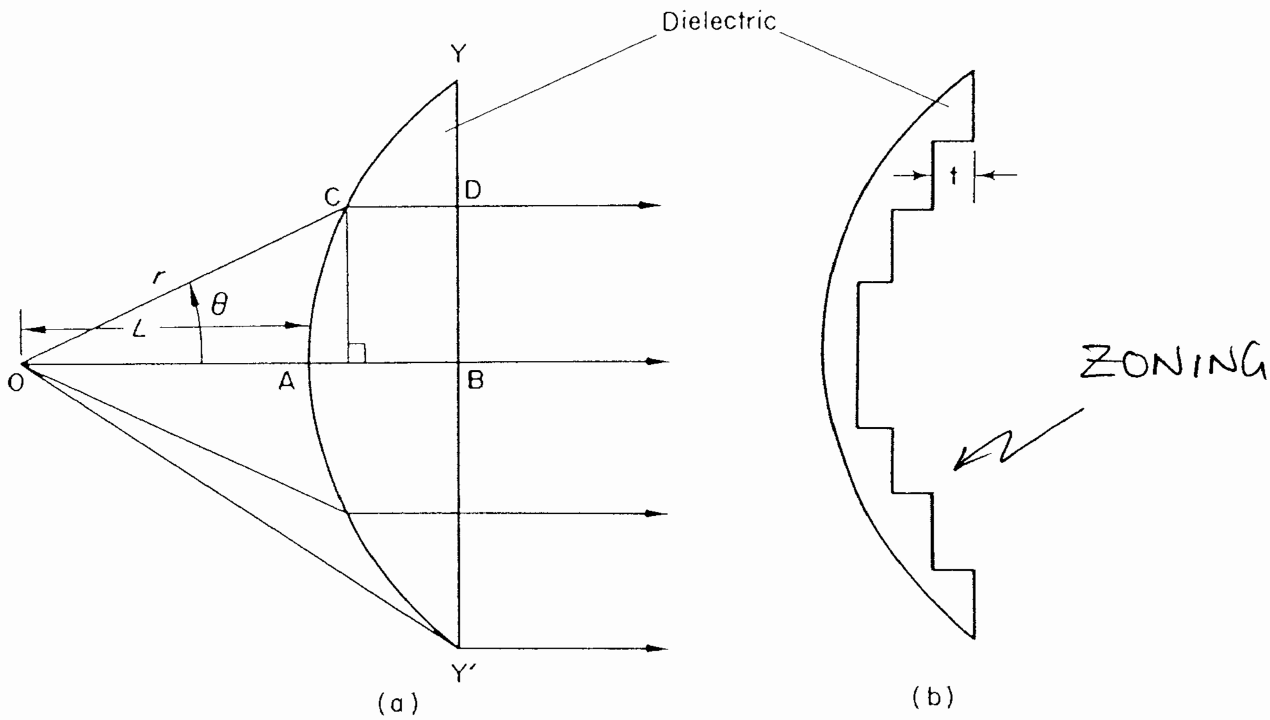
THE SURFACE PROFILE IS GENERALLY HYPERBOLIC, AT LOWER MICROWAVE FREQUENCIES, TO REDUCE THE AMOUNT OF MATERIAL THE LENS IS "ZONED"

ZONING REDUCES WEIGHT, BUT ALSO REDUCES THE BANDWIDTH.



OFFSET NEWTONIAN

OFFSET CASSEGRAINIAN



(a) Dielectric lens

(b) Stepped lens