# PULSE COMPRESSION

PULSE COMPRESSION ALLOWS A RADAR TO UTILIZE A LONG PULSE TO ACHIEVE A LARGE RADIATED ENERGY, BUT SIMULTANEOUSLY TO OBTAIN THE RANGE RESOLUTION OF A SHORT PULSE

THIS CAN BE ACHIEVED BY MODULATION OF THE TRANSMITTED SIGNAL TO WIDEN THE SIGNAL BANDWIDTH.

THE MODULATION IS USUALLY FREQUENCY OR PHASE MODULATION - AMPLITUDE MODULATION IS ALSO POSSIBLE, BUT SELDOMLY USED

THE RECEIVED SIGNAL IS PROCESSED IN A MATCHED FILTER THAT COMPRESSES THE LONG PULSE TO A DURATION OF $1/B$, WHERE $B$ IS THE MODULATED PULSE SPECTRAL BANDWIDTH

PULSE COMPRESSION IS OFTEN USED WHEN THE PEAK POWER REQUIRED OF A SHORT PULSE RADAR CANNOT BE ACHIEVED WITH PRACTICAL TRANSMITTERS

A CONVENTIONAL SHORT-PULSE RADAR MAY BE DESIRED FOR THE FOLLOWING PURPOSES;

* RANGE RESOLUTION: IT IS USUALLY EASIER TO SEPARATE MULTIPLE TARGETS IN RANGE RATHER THAN ANGLE

* RANGE ACCURACY: IF A RADAR IS CAPABLE OF GOOD RANGE RESOLUTION, IT IS ALSO CAPABLE OF GOOD RANGE ACCURACY

* CLUTTER REDUCTION: A SHORT PULSE INCREASES THE TARGET-TO-CLUTTER RATIO BY REDUCING THE CLUTTER CONTAINED WITHIN THE RESOLUTION CELL WITH WHICH THE TARGET COMPETES

A SHORT-PULSE RADAR IS NOT WITHOUT DISADVANTAGES;

* SHORTER PULSE MEANS LARGER BANDWIDTH

* MORE INFORMATION TO PROCESS. MORE COMPLEX SIGNAL PROCESSING REQUIRED

* A WIDER BANDWIDTH CAN MEAN A REDUCTION IN SIGNAL DYNAMIC RANGE

* IF THE TRANSMITTER IS PEAK-POWER LIMITED, THE SHORTER THE PULSE, THE LESS THE ENERGY TRANSMITTED - SHORT-PULSE RADARS ARE OFTEN LIMITED RANGE SYSTEMS

## THE CONCEPT OF PULSE COMPRESSION

WE CAN CONSIDER THE MODULATION APPLIED TO OUR PULSE AS PROVIDING DISTINCTIVE MARKS OVER THE DURATION OF THE PULSE. FOR EXAMPLE;

THE CHANGING FREQUENCY OF A LINEARLY FREQUENCY-MODULATED PULSE IS DISTRIBUTED ALONG THE PULSE AND THUS IDENTIFIES EACH SEGMENT OF THE PULSE (A SORT-OF COMBINED PULSE-CWFM RADAR)

BY PASSING THIS MODULATED PULSE THROUGH A DELAY LINE WHOSE DELAY TIME IS A FUNCTION OF THE FREQUENCY (A DISPERSIVE DELAY LINE, DDL) EACH PART OF THE PULSE EXPERIENCES A DIFFERENT TIME-DELAY, SO THAT IT IS POSSIBLE TO HAVE THE TRAILING EDGE OF THE PULSE SPEEDED-UP AND THE LEADING EDGE SLOWED-DOWN SO AS TO CAUSE A TIME COMPRESSION OF THE PULSE.

THE <u>PULSE-COMPRESSION RATIO</u> IS A MEASURE OF THE DEGREE TO WHICH THE PULSE IS COMPRESSED.

THE PULSE-COMPRESSION RATIO, (PCR) MAY BE DEFINED AS;

$$PCR = \frac{\text{UNCOMPRESSED PULSE WIDTH}}{\text{COMPRESSED PULSE WIDTH}}$$

<u>OR</u>

$$PCR = \text{PULSE SPECTRAL BANDWIDTH} \times T$$

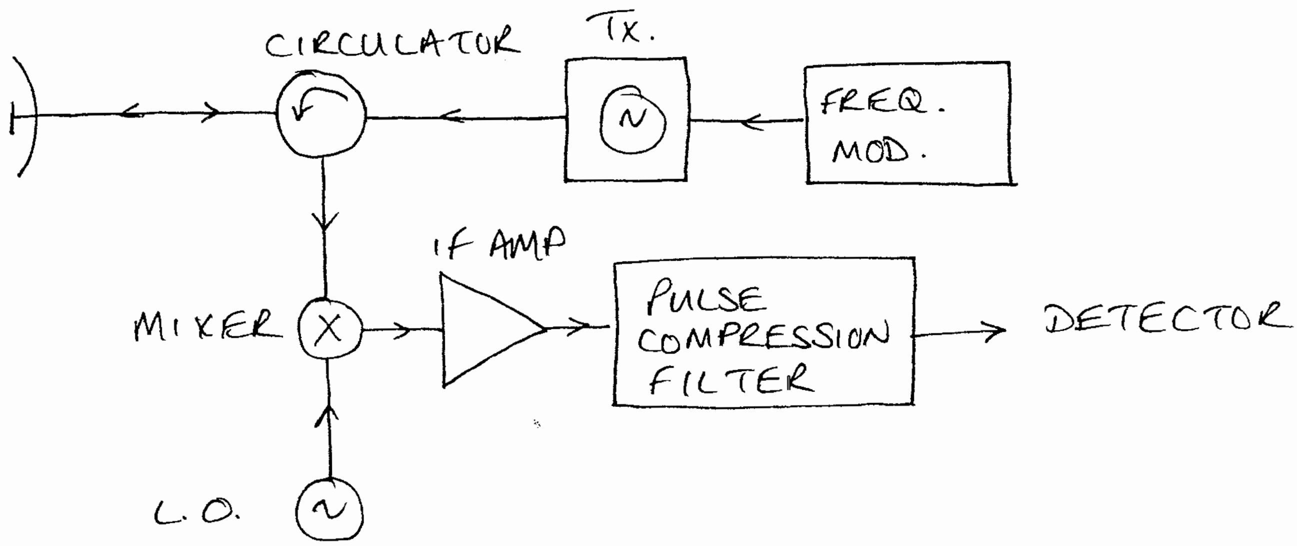
WHERE $T$ = UNCOMPRESSED PULSE WIDTH

THE PULSE-COMPRESSION-RATIO IS GENERALLY $\gg 1$. TYPICALLY THE PCR IS 100-200, BUT CAN BE 1 TO $10^6$ IN SOME CASES.

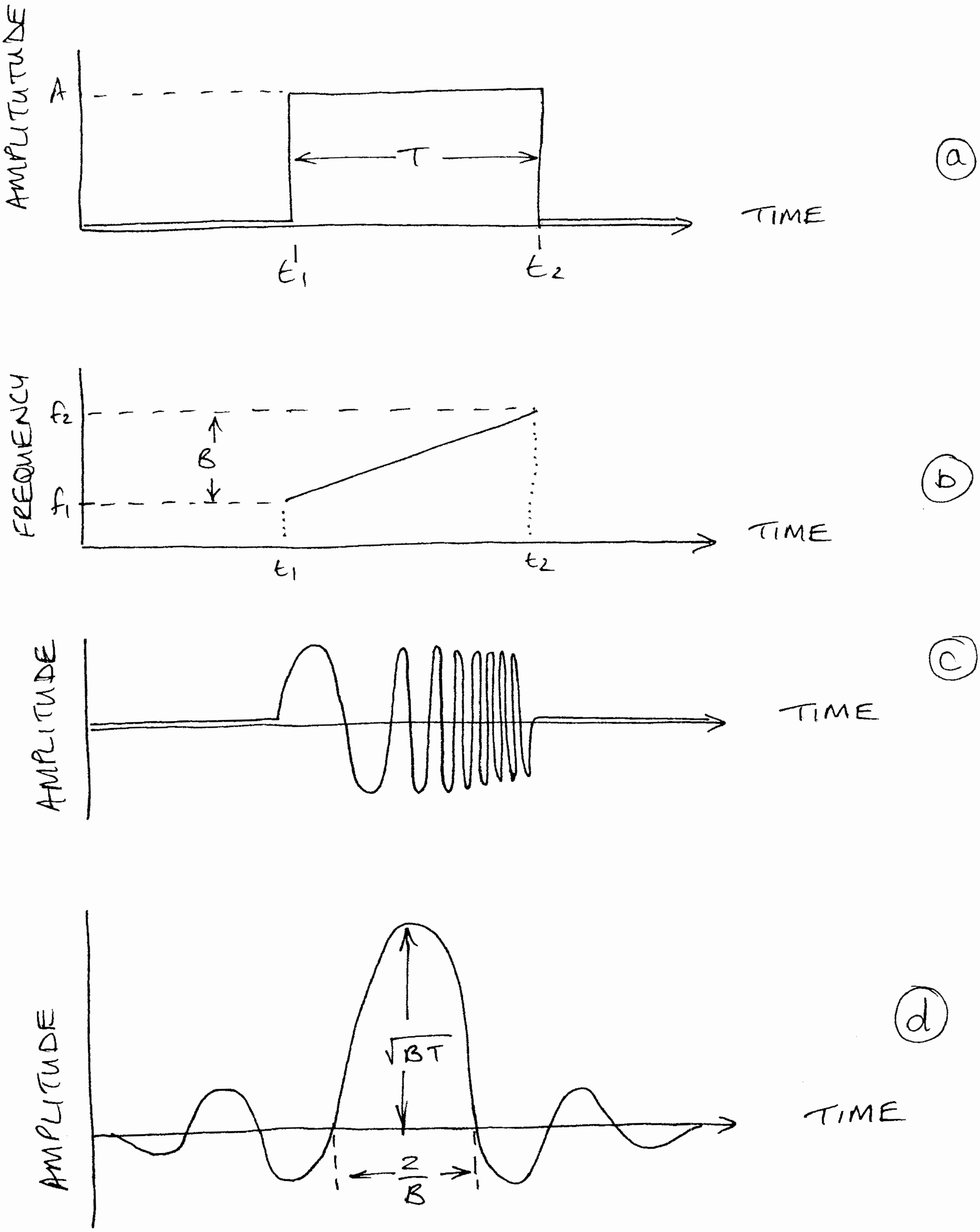
THERE ARE MANY TYPES OF MODULATION USED FOR PULSE COMPRESSION, BUT TWO THAT HAVE SEEN WIDE APPLICATION ARE

* LINEAR FREQUENCY-MODULATION (CHIRP)
* PHASE-CODED PULSE

## LINEAR F.M. PULSE COMPRESSION




LINEAR FM PULSE COMPRESSION PATENTED BY R.H DICKE 1945.




(a) - TRANSMITTED PULSE (WITHOUT CARRIER & WITHOUT MODULATION)
(b) - MODULATION
(c) - TRANSMITTED PULSE WITH MODULATION
(d) - OUTPUT OF PULSE COMPRESSION FILTER

# PULSE COMPRESSION FILTERS

TRADITIONAL APPROACHES TO PULSE COMPRESSION FILTERS INVOLVE THE USE OF DISPERSIVE DELAY LINES (DDLs)

IN RECENT TIMES IT HAS BEEN POSSIBLE TO IMPLEMENT PULSE COMPRESSION SYSTEMS WITH DSP.

HOWEVER DESPITE THE ENORMOUS SIGNAL PROCESSING CAPABILITY OF MODERN DSPs IT IS STILL NOT ENOUGH FOR SOME APPLICATIONS.

## DISPERSIVE DELAY LINES

A NUMBER OF DEVICES HAVE BEEN USED AS DLLs. A MAJORITY OF THESE HAVE EMPLOYED ULTRA-SONIC STRUCTURES.

ULTRASONIC DELAY-LINES OFTEN USE PIEZO-ELECTRIC MATERIALS SUCH AS QUARTZ, OR YIG (YTTRIUM-IRON-GARNET). SUCH TECHNIQUES MAKE USE OF SURFACE ACOUSTIC WAVES (SAW)

SAW DEVICES ARE SIMPLE, LOWCOST, SMALL AND HIGHLY REPRODUCIBLE IN MANUFACTURE

A "TYPICAL" SAW DISPERSIVE DELAY LINE DEVELOPED FOR A LINEAR FM PULSE COMPRESSION RADAR HAD A BANDWIDTH 500 MHZ AND AN UNCOMPRESSED PULSE WIDTH OF 0.46µs. THE CENTRE FREQUENCY WAS 1.3GHZ, AND THE COMPRESSED PULSE WIDTH WAS 3ns (PCR $\hat{=}$ 150). THE FILTER WAS 12mm X 38mm X 58mm.

SAWS HAVE BEEN FABRICATED WITH PCRS OF >10,000 WITH OUTPUT PULSES OF SUB-NANOSECOND DURATION.

## TIME OR RANGE SIDELOBES

THE UNIFORM AMPLITUDE OF THE LINEAR FM WAVEFORM RESULTS IN A COMPRESSED PULSE SHAPE HAVING A SHAPE OF THE FORM;

$$\frac{\sin(\pi B t)}{\pi B t}$$

THEREFORE THERE ARE TIME OR RANGE SIDELOBES EITHER SIDE OF THE MAIN LOBE

THE RANGE SIDELOBES CAN CAUSE PROBLEMS - LARGE TARGETS NEARBY MAY MASQUERADE THEMSELVES AS, OR MASK SMALLER TARGETS AT LONGER RANGE.

THE RANGE-SIDELOBES CAN BE CHANGED, BY CHANGING THE WEIGHTING OF THE TRANSMITTED PULSE, OR BY CHANGING THE WEIGHTING OF THE RECEIVED SIGNAL

| WEIGHTING FUNCTION | PEAK SIDELOBE (dB) | MAINLOBE WIDTH |
|---|---|---|
| UNIFORM | -13.2 | 1.0 |
| $\cos^2(\pi f/B)$ | -31.7 | 1.65 |
| DOLPH-CHEBYSHEV | -40.0 | 1.35 |
| HAMMING | -42.8 | 1.50 |

HOWEVER, THE BETTER THE RANGE SIDELOBE SUPRESSION, THE WORSE THE SIGNAL TO NOISE RATIO DUE TO THE LOSS DUE TO THE WEIGHTING FUNCTION

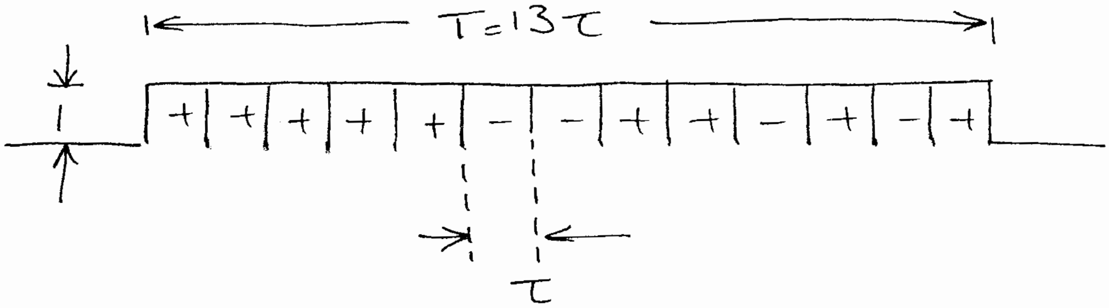
# PHASE-CODED PULSE COMPRESSION

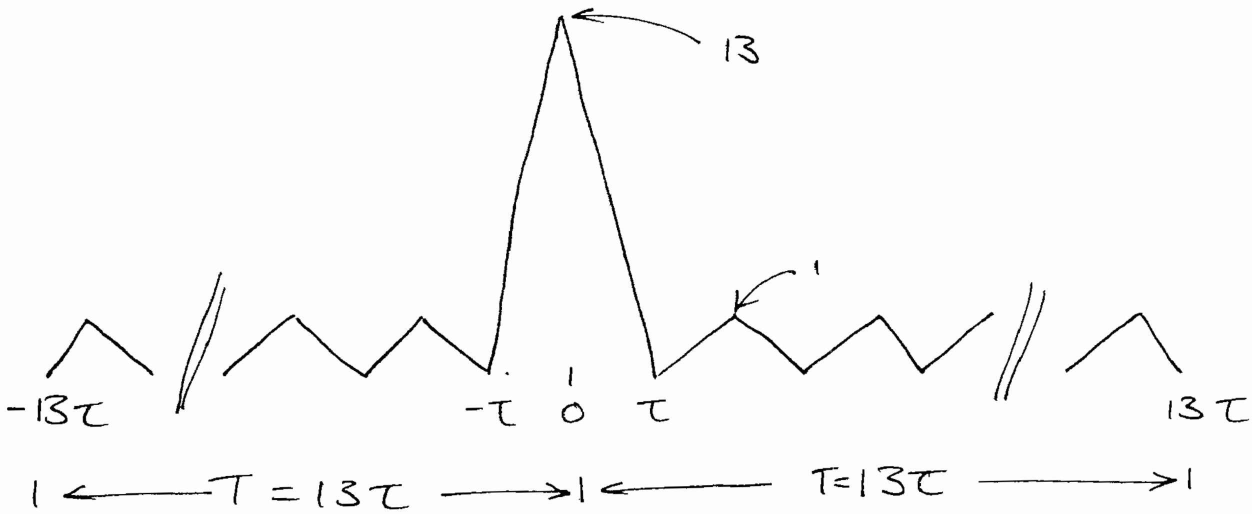
IN THIS FORM OF PULSE COMPRESSION, A LONG PULSE OF DURATION $T$ IS DIVIDED INTO $N$ SUBPULSES EACH OF WIDTH $\tau$. THE PHASE OF EACH SUBPULSE IS CHOSEN TO BE EITHER 0 OR $\pi$.

IF THE SELECTION OF THE PHASE IS MADE AT RANDOM, THE WAVEFORM APPROXIMATES A NOISE-MODULATED SIGNAL WITH THE OUTPUT OF THE RECEIVER MATCHED FILTER BEING A SPIKE OF WIDTH $\tau$ AND AN AMPLITUDE $N$ TIMES GREATER THAN THAT OF THE LONG PULSE

ONE OF THE MOST COMMANLY USED PHASE CODE SEQUENCES IS THE BARKER CODE - THESE RESULT IN EQUAL SIDELOBES

| CODE LENGTH | CODE ELEMENTS | SIDELOBES (dB) |
|---|---|---|
| 2 | + -, + + | -6.0 |
| 3 | + + - | -9.5 |
| 4 | + + - +, + + + - | -12.0 |
| 5 | + + + - + | -14.0 |
| 7 | + + + - - + - | -16.9 |
| 11 | + + + - - - + - - + - | -20.8 |
| 13 | + + + + + - - + + - + - + | -22.3 |




OTHER CODES CAN BE USED - MAXIMAL LENGTH SEQUENCES

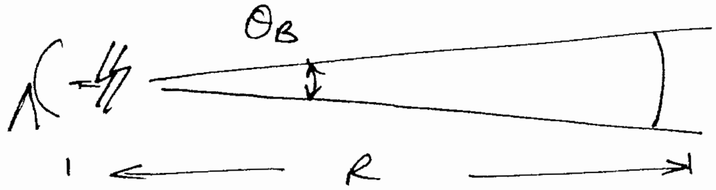
## OTHER PULSE-COMPRESSION WAVEFORMS

* NON-LINEAR FM
* POLY-PHASE CODES
* COMPOUND BARKER CODES

# SYNTHETIC APERTURE RADAR

A SYNTHETIC APERTURE RADAR (SAR) ACHIEVES HIGH RESOLUTION IN THE CROSS-RANGE DIMENSION BY TAKING ADVANTAGE OF THE MOTION OF THE VEHICLE CARRYING THE RADAR TO SYNTHESIZE THE EFFECT OF A LARGE ANTENNA APERTURE.

THE RESOLUTION IN THE CROSS-RANGE DIMENSION OF A CONVENTIONAL ANTENNA IS;

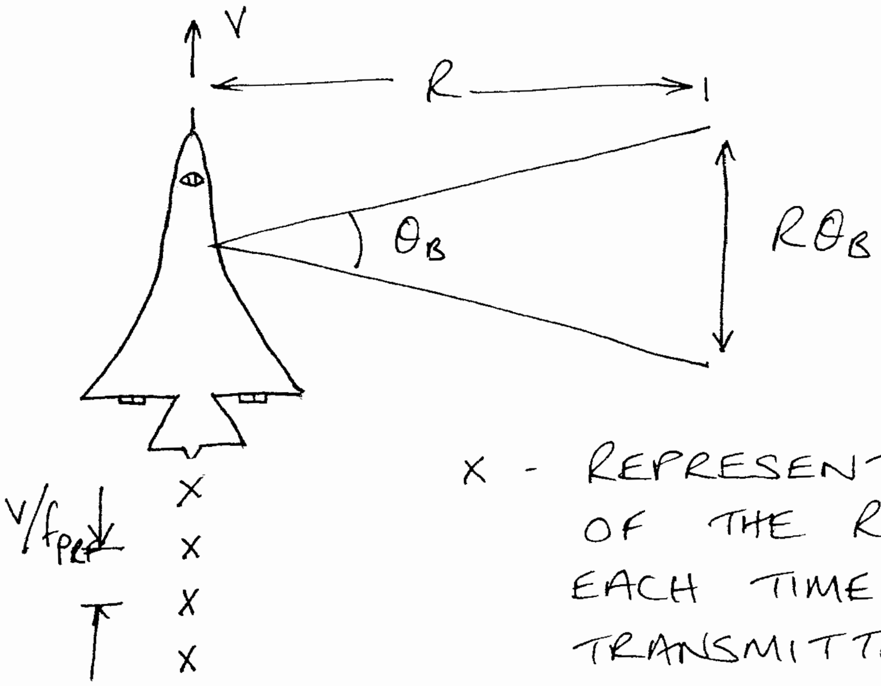



$$\delta_{CR} = R\theta_B$$

R- RANGE ; $\theta_B$ - BEAMWIDTH.

IF WE HAD $\theta_B = 0.2^\circ$ AND $R = 100\,km$
$\delta_{CR} \doteq 350\,m$ THIS IS FAR LARGER THAN THE RANGE RESOLUTION ACHIEVABLE WITH PULSE COMPRESSION.

SAR TECHNIQUES PERMIT THE ATTAINMENT OF HIGH-RESOLUTION BY USING THE MOTION OF THE VEHICLE TO GENERATE THE ANTENNA APERATURE <u>SEQUENTIALLY</u> RATHER THAN <u>SIMULTANEOUSLY</u>




X - REPRESENTS THE POSITION OF THE RADAR ANTENNA EACH TIME A PULSE IS TRANSMITTED

THE "ELEMENT" SPACING OF THE SYNTHESIZED ANTENNA IS $V/f_{PRF}$

FOR A CONVENTIONAL ANTENNA;

$$\theta_B = \frac{k\lambda}{D} \qquad k \simeq 1.27$$

HENCE

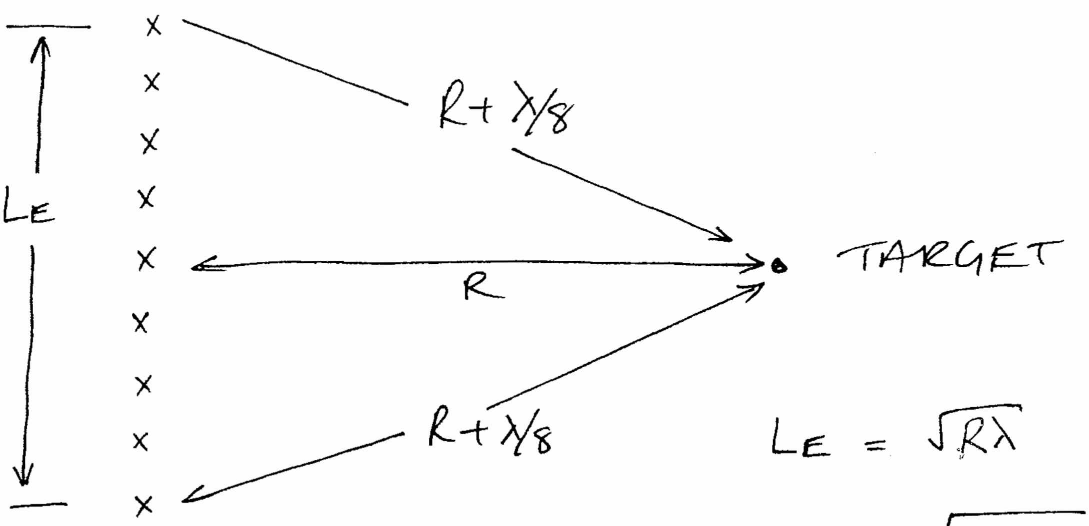
$$\delta_{cr} = \frac{Rk\lambda}{D}$$

FOR A SYNTHETIC APERTURE ANTENNA OF EFFECTIVE LENGTH $L_E$ IS SIMILARLY;

$$\theta_s = \frac{k\lambda}{2L_E}; \qquad L_E \leq R\theta_B$$

A LIMIT ON THE EFFECTIVE LENGTH IS DETERMINED BY THE FAR-FIELD OF THE SYNTHETIC APERTURE; THAT IS, WE NEED TO RESTRICT THE APERTURE SIZE SO THAT THE PHASE-FRONT CAN BE CONSIDERED AS A PLANE WAVE - IF THIS CONDITION APPLIES THE SAR IS SAID TO BE UNFOCUSED

THE MAXIMUM APERTURE OF AN UNFOCUSED SAR IS SUCH THAT THE DIFFERENCE BETWEEN MINIMUM AND MAXIMUM PATHS (TWO-WAY) IS $\lambda/4$.




$$L_E = \sqrt{R\lambda}$$

$$\delta_{CR} = \frac{\sqrt{R\lambda}}{2}$$

IN THE FOCUSED CASE;

$$L_E = \frac{R\lambda}{D} \; ; \quad \delta_{CR} = R\theta_s = \frac{D}{2}$$

INDEPENDENT ON RANGE AND WAVELENGTH ONLY A FUNCTION OF D.