COHERENT SYSTEMS IN THE TERAHERTZ FREQUENCY RANGE: ELEMENTS OPERATION & EXAMPLES

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TERAHERTZ COHERENT SYSTEMS APPLICATIONS

RADIOMETRY / SPECTROSCOPY

ASTRONOMY
ATMOSPHERIC REMOTE SENSING
ALL–WEATHER SYNTHETIC VISION SYSTEMS
CONTRABAND DETECTION

HIGH POWER

PLASMA HEATING
HIGH ENERGY ACCELERATORS

PLASMA DIAGNOSTICS

THERMAL IMAGING
DENSITY PROBING
BACKSCATTER MEASUREMENTS

COMMUNICATIONS

PERSONAL & VEHICULAR
DIGITAL DATA LINKS
TV REMOTE / STUDIO LINKS

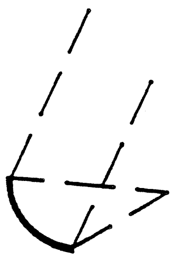
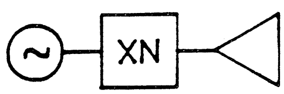
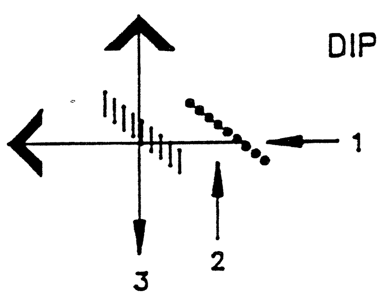
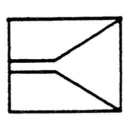
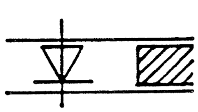
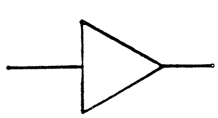
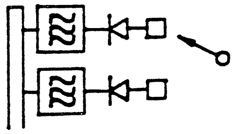
MATERIALS MEASUREMENT AND COMMERCIAL PROCESS CONTROL

PAPER MAKING
HV CABLE MANUFACTURING

RADAR SYSTEMS

MILITARY – SEEKERS, INSTRUMENTATION, AND MODELING
AUTOMOTIVE COLLISION AVOIDANCE
ATMOSPHERE, METEOROLOGY, GROUND, ICE, AND FOLIAGE

COMPONENTS OF COHERENT SYSTEMS AT MILLIMETER & SUBMILLIMETER WAVELENGTHS

	INPUT OPTICS	COLLIMATING MIRRORS AND LENSES
	SIGNAL PROCESSING ELEMENTS	POLARIZING GRIDS WAVEPLATES
	COHERENT SOURCE	LOCAL OSCILLATOR; TRANSMITTER
	DIPLEXER	COMBINATION OF LOCAL OSCILLATOR AND SIGNAL
	ANTENNA/FEED ELEMENTS	EFFICIENCY, BEAMWIDTH, BANDWIDTH, CONSTRUCTION INTEGRABILITY
	MIXER	CONVERSION LOSS; NOISE; L.O. POWER; BANDWIDTH
	IF SYSTEM	NOISE; BANDWIDTH
	DETECTION/SIGNAL PROCESSING	SPECTROMETERS: FREQUENCY COVERAGE; RESOLUTION; FLEXIBILITY; POWER CONSUMPTION

BRIEF OVERVIEW OF SELECTED COMPONENTS

EMPHASIZE AREAS THAT I FEEL DESERVE MORE ATTENTION THAN THEY ARE RECEIVING AT PRESENT

[1] MATERIALS MEASUREMENT

FUNDAMENTAL FOR MANY ASPECTS OF SYSTEMS DESIGN

NEED <u>MORE</u> DATA, <u>BETTER</u> DATA, AND <u>BETTER</u> <u>ACCESS</u>

REXOLITE DATA FROM G. J. SIMONIS, J. P. SATTLER, T. L. WORCHESKY, AND R. P. LEAVITT, *INT. J. INFRARED AND MILLIMETER WAVES*, VOL. 5, 57 – 72, 1984.

BORON NITRIDE DATA FROM A. J. GATESMAN, R. H. GILES, AND J. WALDMAN *PROC. MATERIALS RESEARCH SOCIETY SYMPOSIUM ON WIDE BANDGAP SEMICONDUCTORS*, 1991 FALL MEETING, BOSTON

INTERCOMPARISON OF TECHNIQUES FOR DETERMINATION OF NEAR MILLIMETER DIELECTRIC PROPERTIES

JAMES BIRCH ET AL. – NATIONAL PHYSICAL LABORATORY
TEDDINGTON, MIDDLESEX
U.K. TW11 OLW

REPORT DES 115, OCTOBER 1991

[2] QUASIOPTICAL COMPONENTS

HOW CAN THEY BE FABRICATED IN SUBMILLIMETER REGION ?

TRADITIONAL MACHINING METHODS BECOME VERY DIFFICULT AND EXPENSIVE–

NEED TO FIND CONSTRUCTIVE COMBINATIONS OF METAL–WORKING AND SEMICONDUCTOR PROCESSING APPROACHES SUCH AS SELECTIVE ETCHING

EXAMPLES:

PROCESSING SILICON TO FABRICATE TWO DIMENSIONAL IMAGING HORN ANTENNA ARRAYS (REBEIZ ET AL. **IEEE MTT** 38, 1473 (1990))

ETCHING AND PLATING SILICON TO MAKE DICHROIC PLATE HIGH PASS FILTERS IN 1000 GHZ RANGE
(SIEGEL AND LICHTENBERGER **1990 MTT–S SYMP. DIGEST,** 1341)

RADIOMETRY AND SPECTROSCOPY : ASTRONOMY

OBSERVING LOCATION DEPENDS PRIMARILY ON FREQUENCY:

GROUND – BASED
AIRPLANE AND BALLOONS: KAO; SOFIA
SPACE: SWAS; SMIM; FIRST

[1] SENSITIVITY

HIGHEST SENSITIVITY ALWAYS REQUIRED

CRYOGENIC COOLING IS ACCEPTABLE

BROADBAND SYSTEMS WILL BE REQUIRED FOR FUTURE SYSTEMS

[2] IMAGING SYSTEMS

FOCAL PLANE ARRAYS DEVELOPED FOR MILLIMETER RANGE:

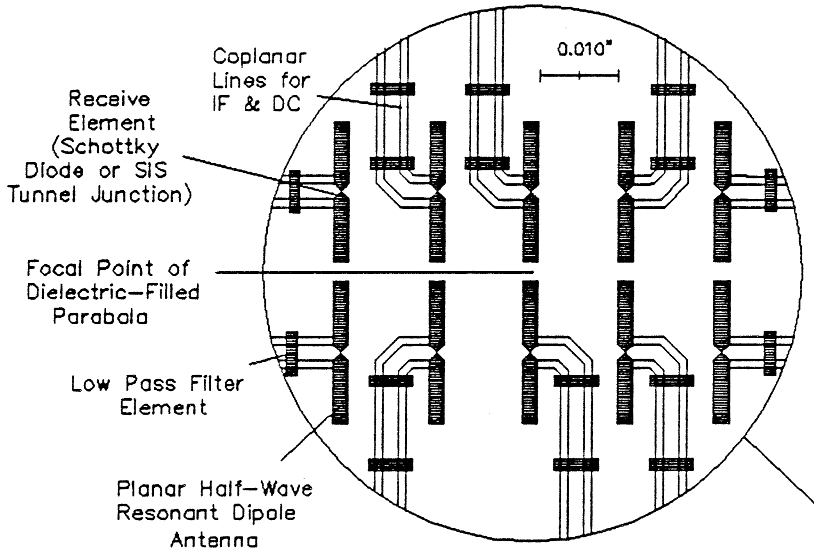
FCRAO 15 – ELEMENT QUARRY ARRAY 85 – 115 GHZ
NRAO 8–ELEMENT ARRAY IN 230 GHZ RANGE

CANNOT SACRIFICE FEED EFFICIENCY SIGNIFICANTLY JUST TO OBTAIN LARGER NUMBER OF ELEMENTS DUE TO COST AND COMPLEXITY OF ASSOCIATED SIGNAL PROCESSING.

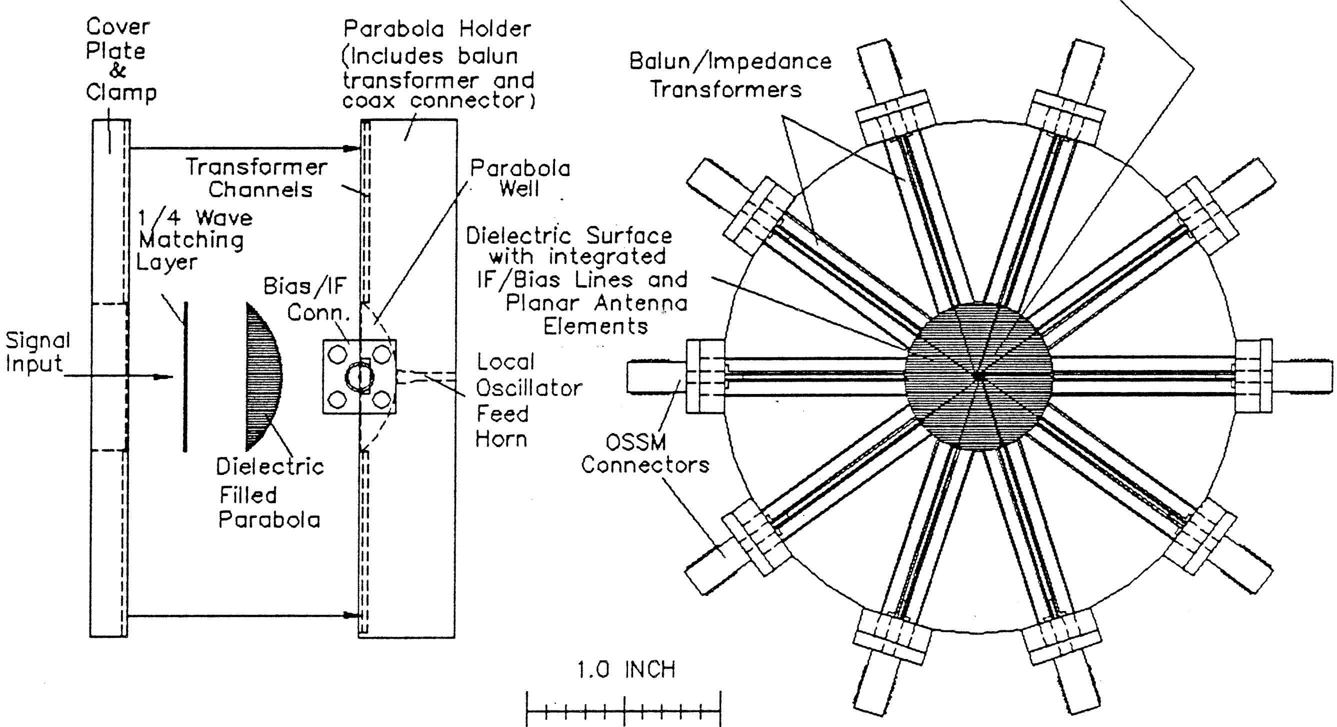
[3] OTHER COMPONENT DEVELOPMENT

RAPID PROGRESS IN FREQUENCY MULTIPLIER SOURCES, BUT FURTHER DEVELOPMENT REQUIRED FOR GREATER BANDWIDTH AND REACHING HIGHER FREQUENCIES

PLANAR HETERODYNE ARRAY USING A DIELECTRIC-FILLED PARABOLA



BLOW UP SHOWING ANTENNA ELEMENTS



EXPLODED VIEW (SIDE)

TOP VIEW (COVER REMOVED)

P.H. Siegel California Institute of Technology Jet Propulsion Laboratory

RADIOMETRY:

AIRCRAFT ALL WEATHER LANDING SYSTEM

APPROACH

FOCAL PLANE IMAGING SYSTEM AT 94 GHZ TO PROVIDE SYNTHETIC VISION CAPABILITY FOR AIRCRAFT LANDING IN ALMOST ALL WEATHER CONDITIONS

MILLIMETER – WAVE IMAGING ALLOWS GOOD VISIBILITY OF RUNWAY BOUNDARIES AND POSSIBLY DANGEROUS OBSTACLES FROM APPROPRIATE DISTANCE.

FOCAL PLANE RADIOMETRIC IMAGING PERMITS REAL – TIME (30 / SECOND) UPDATE RATE

IMAGES READILY INTERPRETABLE WITHOUT EXTENSIVE PROCESSING

HEADS–UP DISPLAY STRAIGHTFORWARD TO IMPLEMENT

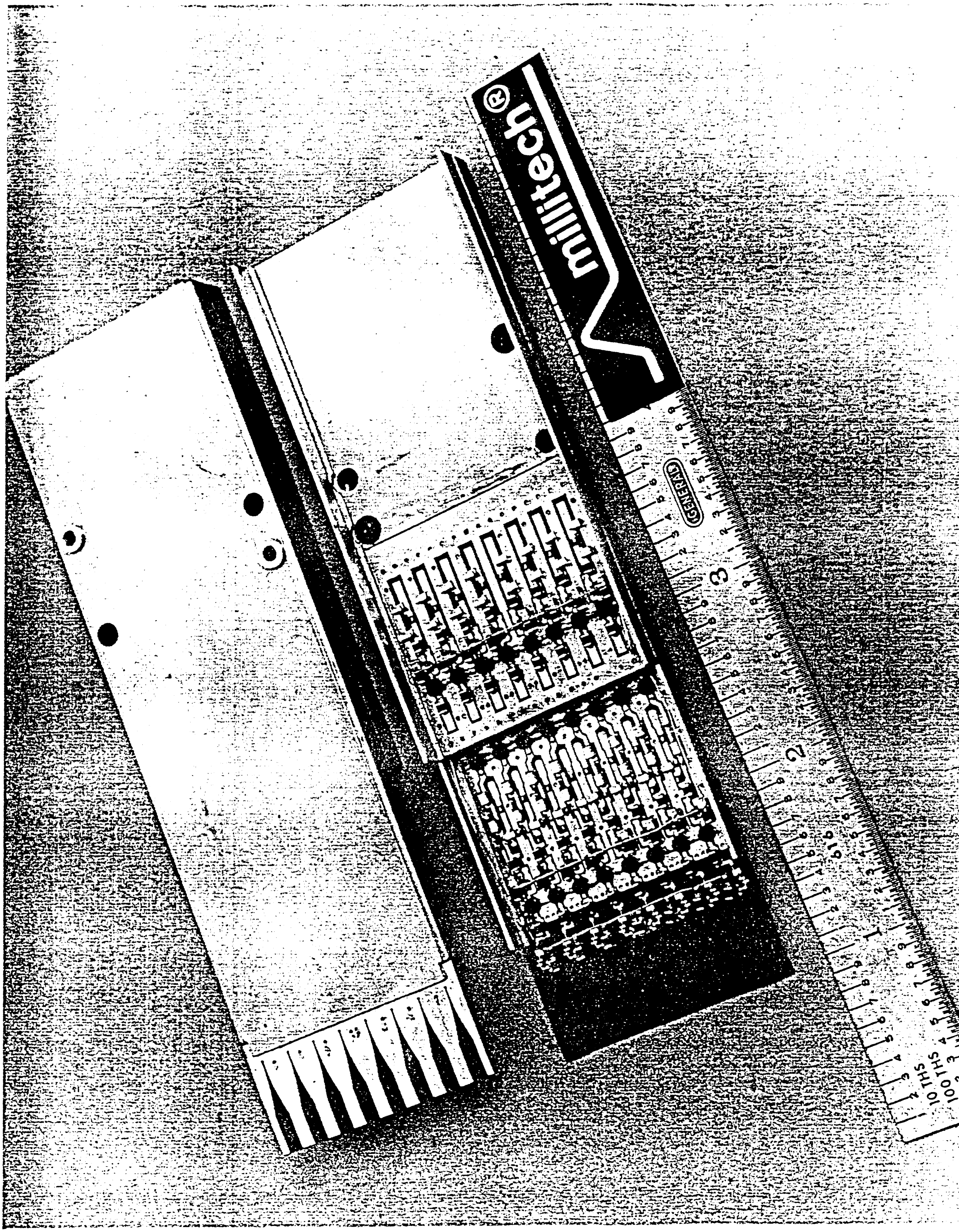
TECHNOLOGY:

FOCAL PLANE ARRAY OF 256 (TO DATE) PIXELS UTILIZING CONSTANT – WIDTH SLOT ANTENNAS

SINGLE – ENDED HARMONIC MIXERS WITH QUASIOPTICAL LOCAL OSCILLATOR INJECTION

DICKE –TYPE LOAD COMPARISON ESSENTIAL
MECHANICAL OR ELECTRONIC (QUASIOPTICAL HYBRID OR MONOLITHIC) REALIZATIONS POSSIBLE

COMPACT OPTICS


millitech®
GENERAL
10 THS
100 THS

DETECTION OF CONCEALED WEAPONS AND CONTRABAND MATERIAL

PROBLEM:

- DETECTION OF PLASTIC WEAPONS AND EXPLOSIVES CONCEALED BENEATH CLOTHING OF AIRLINE PASSENGERS.

CONSTRAINTS:

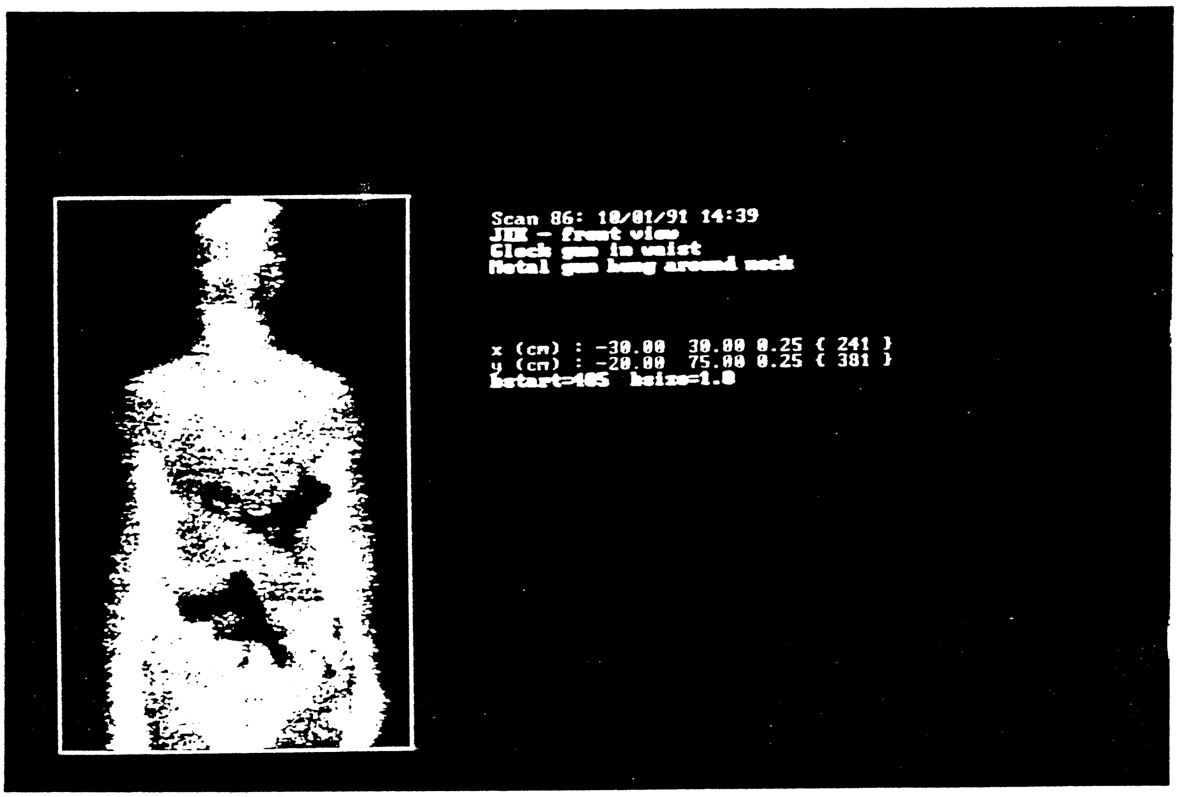
- EFFECTIVE PERFORMANCE
- NON-INVASIVE OPERATION
- RAPID PROCESSING

TECHNICAL APPROACH:

- ACTIVE (REFLECTING) AND PASSIVE (RADIOMETRIC) MILLIMETER-WAVELENGTH IMAGING SYSTEMS

- RADIOMETRIC SYSTEM LEAST INVASIVE AND OFFERS GOOD FIDELITY

- CLOSE FOCUSED OPTICS AND FOCAL PLANE ARRAY



Passive Line Scan 94 GHz Millimeter Wave Image

RADIOMETRY: ATMOSPHERIC REMOTE SENSING

[1] ISSUES:

MEASUREMENT OF TRACE CONSTITUENTS INCLUDING : H_2O
O_3
ClO
N_2O

PHYSICAL CONDITION (TEMPERATURE) PROFILING

DELAY MEASUREMENTS FOR RADAR ALTIMETERS

MESOSPHERIC WIND VELOCITY DETERMINATIONS

TRACE EMISSIONS FROM LOCALIZED SOURCES

[2] OBSERVING LOCATIONS

GROUND – BASED: O_3 AND ClO MONITORING NETWORK

ANTARCTIC AND POLAR REGIONS

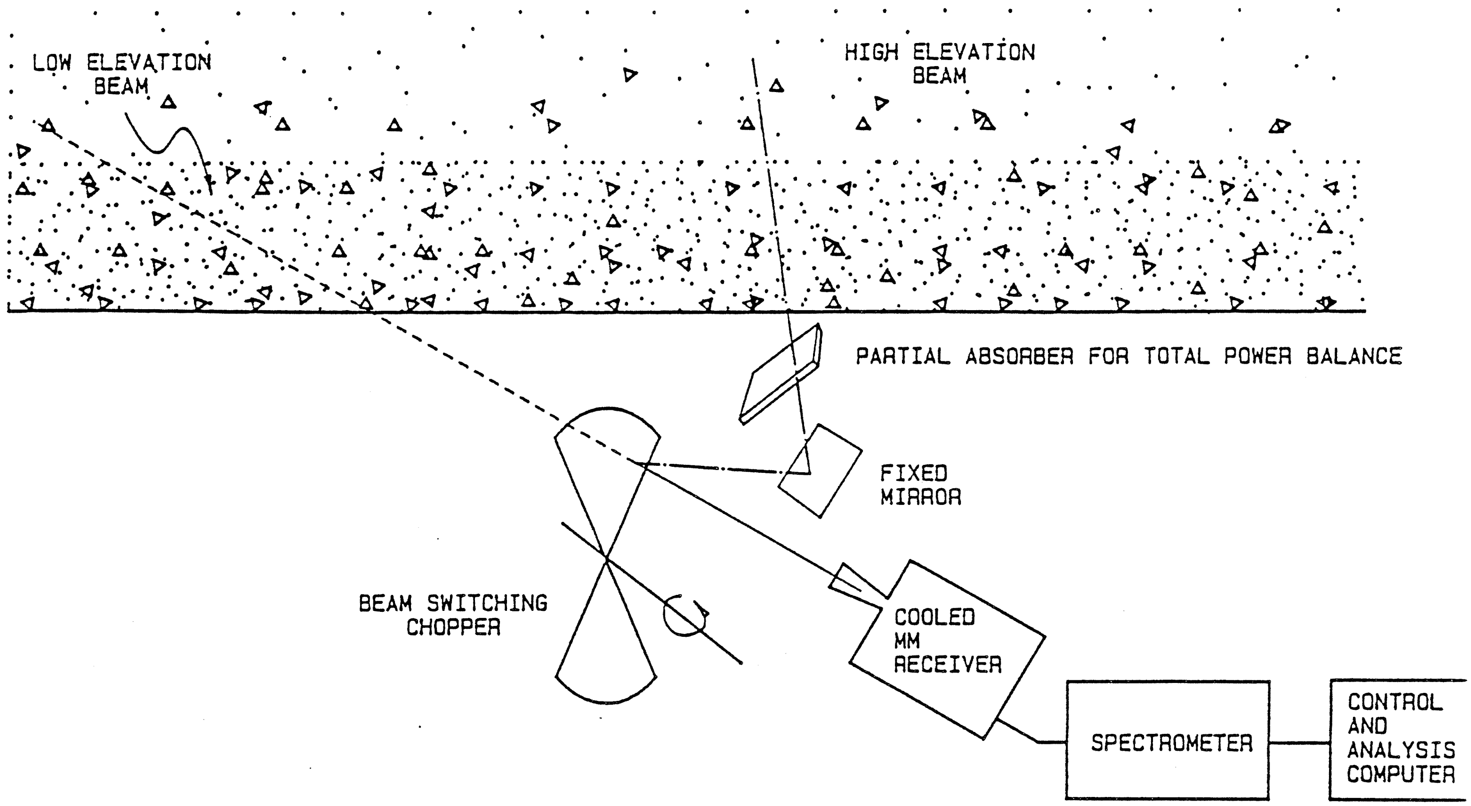
AIRPLANE: USEFUL AS TEST PLATFORM AND FOR STUDY OF LOCALIZED PHENOMENA

SPACE : UARS – SUCCESSFULLY OPERATING !

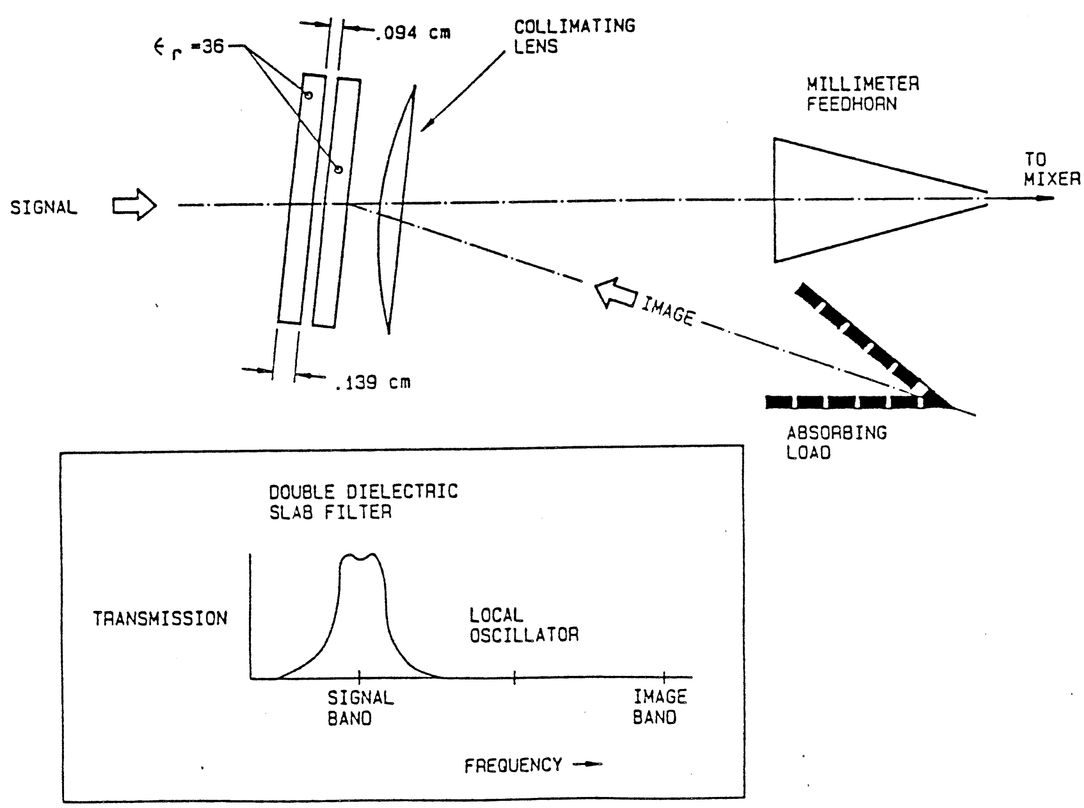
MAS (SHUTTLE LIMB – SOUNDER)

EOS (EARTH OBSERVING SYSTEM)

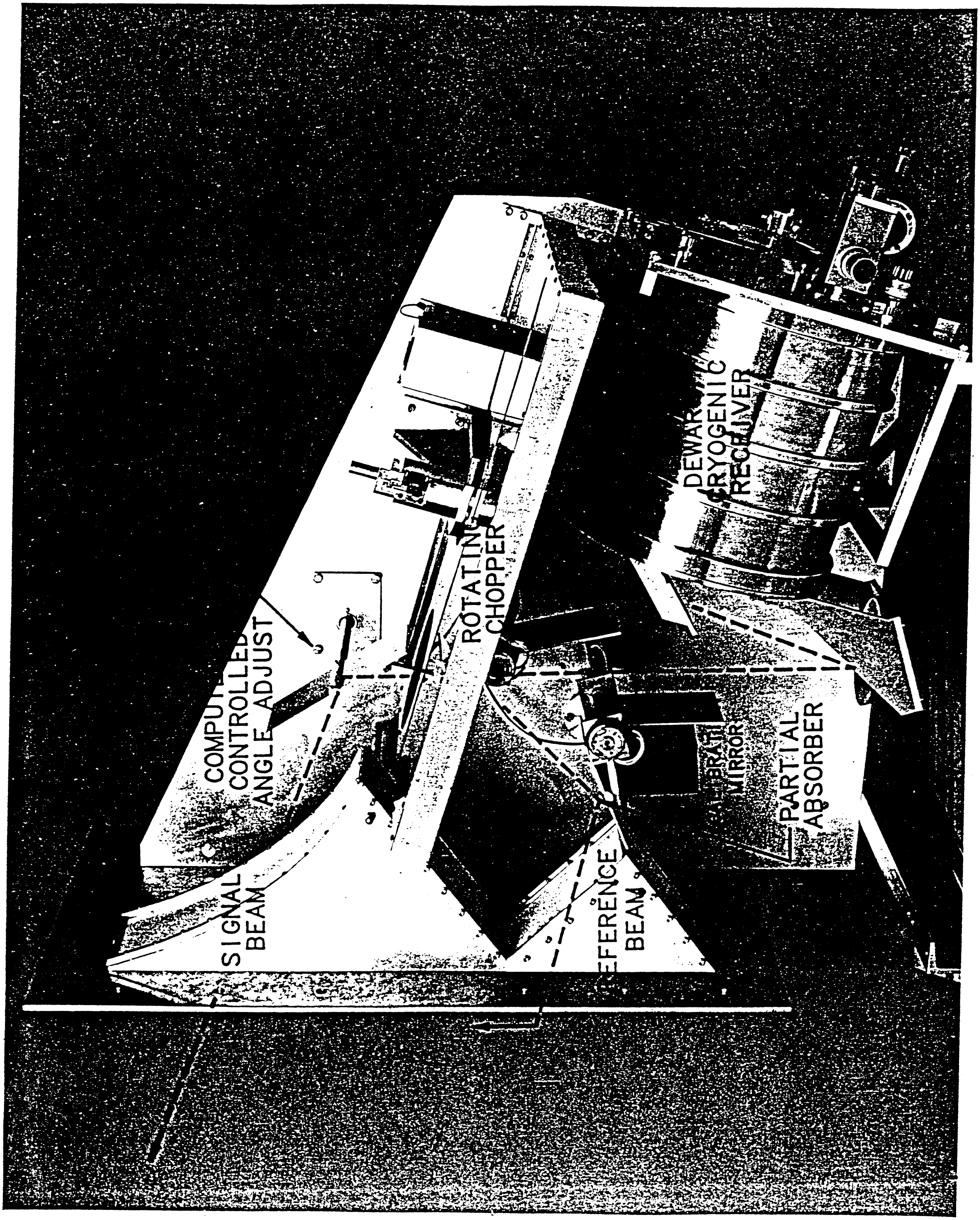
AMSU – B / METEOSAT

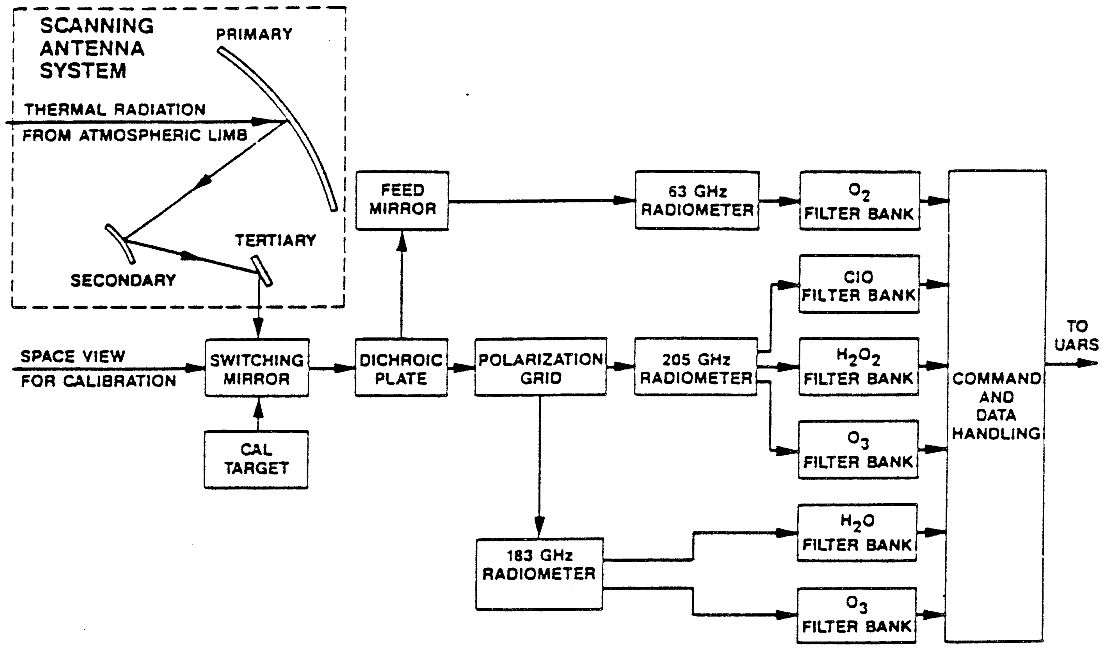


CONFIGURATION FOR GROUND-BASED RADIOMETER TO STUDY ATMOSPHERIC TRACE GASES

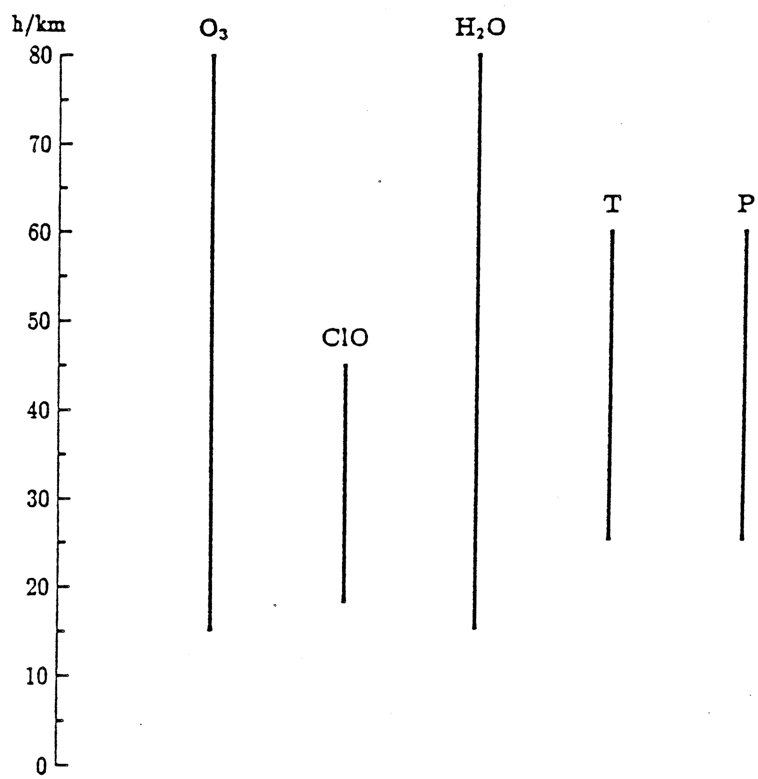


DIELECTRIC SLAB SINGLE-SIDEBAND FILTER FOR 279 GHZ C10 RADIOMETER


COMPUTE
CONTROLLED
ANGLE ADJUST
ROTATING
CHOPPER
DEWAR
CRYOGENIC
RECEIVER
ALIBRAT
MIRROR
PARTIAL
ABSORBER
SIGNAL
BEAM
EFERENCE
BEAM



UARS MICROWAVE LIMB SOUNDER INSTRUMENT SIGNAL FLOW PATH



UARS - MLS TARGETS AND ALTITUDE RANGES

PLASMA DIAGNOSTICS

THERMAL IMAGING – RADIOMETRY WITH HIGH TIME RESOLUTION

EXTREMELY BROADBAND AND/OR SWEPT – FREQUENCY

DENSITY PROFILING – MEASUREMENT OF ELECTRON COLUMN DENSITY THROUGH PLASMA

INTERFEROMETERS – EITHER RADIO OR OPTICAL TYPES DEPENDING ON WAVELENGTH

SCATTERING EXPERIMENTS – PROBE TURBULENCE AND SCALE OF FLUCTUATIONS IN PLASMA

EXAMPLE OF PLASMA DIAGNOSTIC SYSTEM

2 – MM WAVELENGTH 180 DEGREE BACKSCATTER IMAGING SYSTEM DEVELOPED BY DR. P. EFTHIMION (PRINCETON PLASMA LABORATORY) AND E.L. MOORE ET. AL. (MILLITECH CORPORATION)

INCLUDES PHASELOCKED TRANSMITTER AND 64 ELEMENT FOCAL PLANE IMAGING ARRAY

COMMUNICATIONS

APPLICATIONS:

- PERSONAL
- VEHICULAR – CAR TRAIN AND PLANE
- DIGITAL DATA LINKS – SATELLITE AND GROUND
- MILITARY COMMUNICATIONS (MILSTAR)
- TV REMOTE – STUDIO LINKS

DEVELOPMENTS IN FIELD HAVE BEEN REVIEWED BY H. MEINEL IN PROC. 18th EUROPEAN MICROWAVE CONFERENCE, STOCKHOLM, pp. 1203 – 1216, 1988

RADAR SYSTEMS

- **MILITARY RADAR SYSTEMS**

  INSTRUMENTATION RADARS

  SEARCH RADARS

  SEEKERS

  HELICOPTER OBSTACLE AVOIDANCE SYSTEMS

- **AUTOMOTIVE RADAR**

  PRESENTLY VERY ACTIVE FIELD

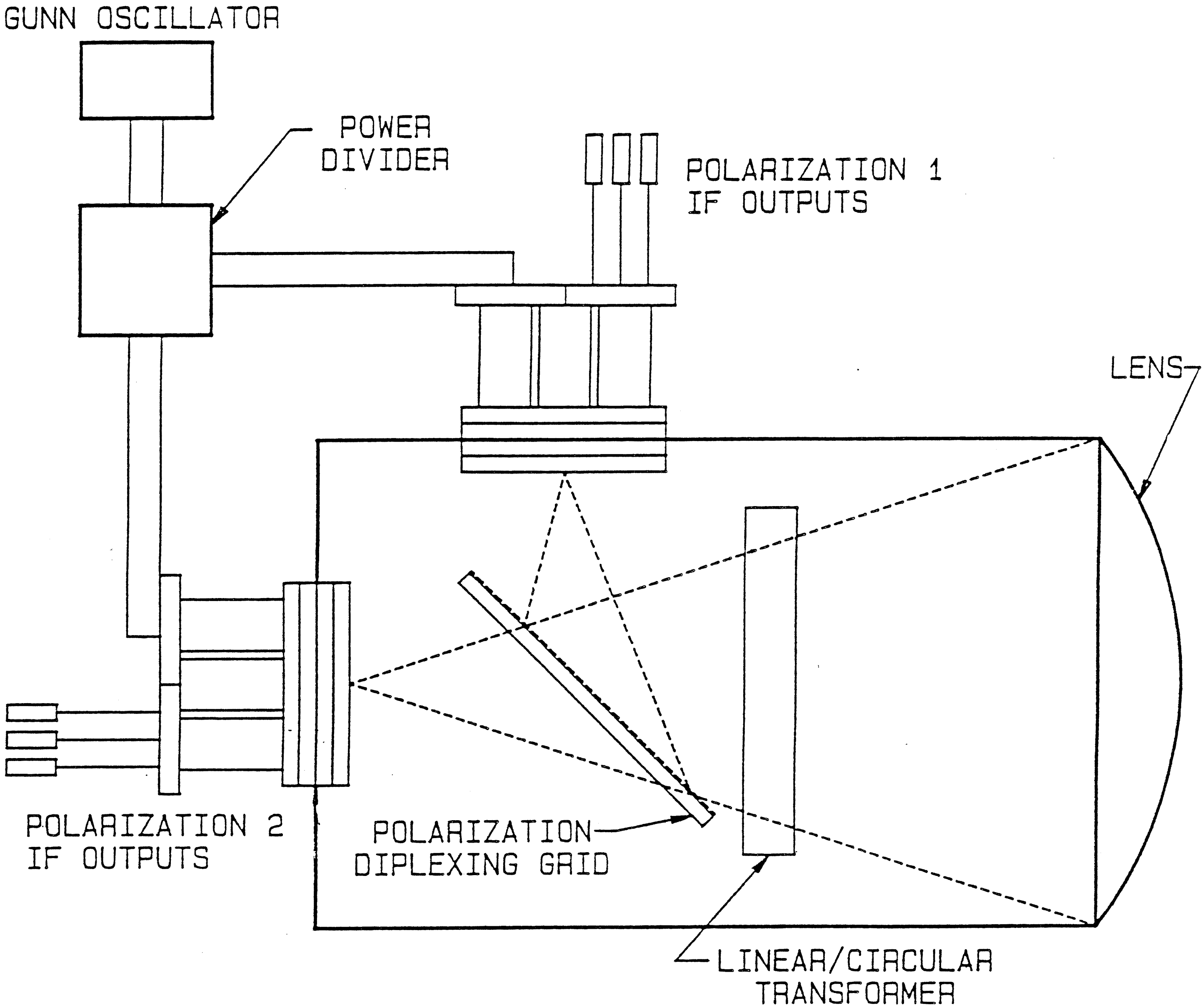
  GOALS ARE COLLISION AVOIDANCE AND ULTIMATELY AUTOMATIC CONTROL OF VEHICLE

- **ATMOSPHERE** CLOUD STRUCTURE (ICE & WATER)
  METEOROLOGY

- **REMOTE SENSING** OCEANS
  VEGETATION
  ICE

- **MODELING**

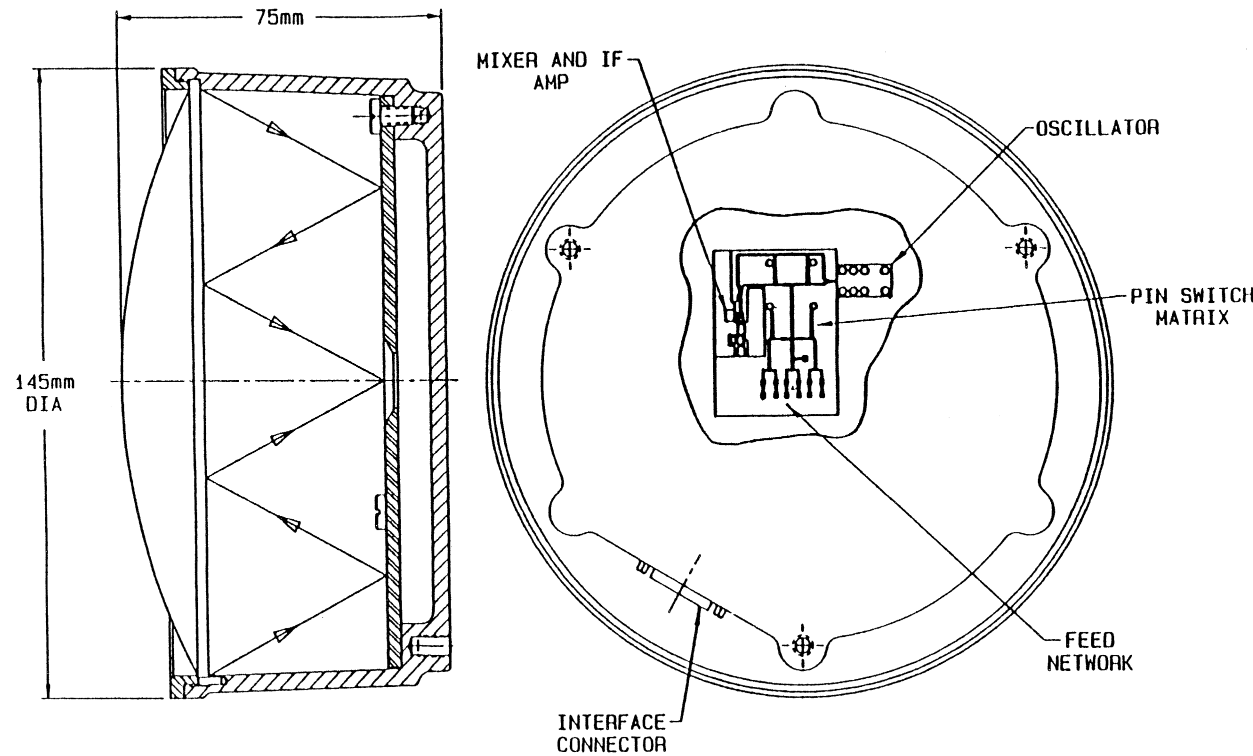
  MILLIMETER / SUBMILLIMETER MODELING OF LOWER FREQUENCY RADAR SYSTEMS AND TARGETS



DUAL POLARIZATION MONOPULSE LENS ANTENNA

SPECIFICATIONS SUMMARY

TYPE: PULSE
TRANSMITTER FREQUENCY: 77GHz
PULSE WIDTH: 40ns
RISE/FALL TIME: 4ns
ANTENNA: THREE BEAM SCANNING
BEAM WIDTH: 2° ELEVATION AND AZIMUTH
IF BANDWIDTH: 1KHz TO 200MHz



MILLITECH AUTOMOBILE RADAR FRONT END

millitech

MATERIALS MEASUREMENT AND MANUFACTURING PROCESS CONTROL

MAJOR CONSIDERATIONS

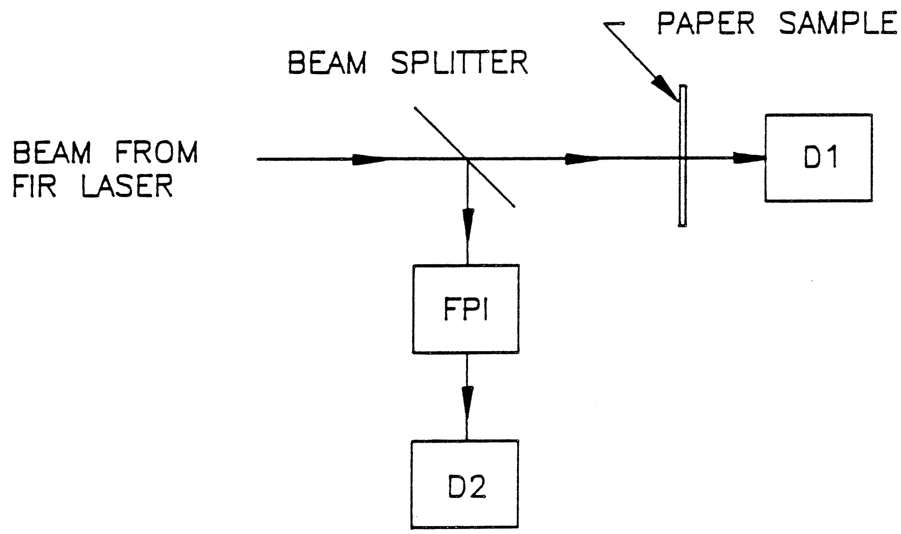
- DEMANDS EXTREMELY RUGGED SYSTEMS
- COST IS A CRITICAL FACTOR
- MOST INDUSTRIES ARE CONSERVATIVE AND NEED TO BE CONVINCED OF VALUE OF NEW SYSTEM
- WHAT ARE THE UNIQUE CAPABILITIES OF TERAHERTZ RANGE?

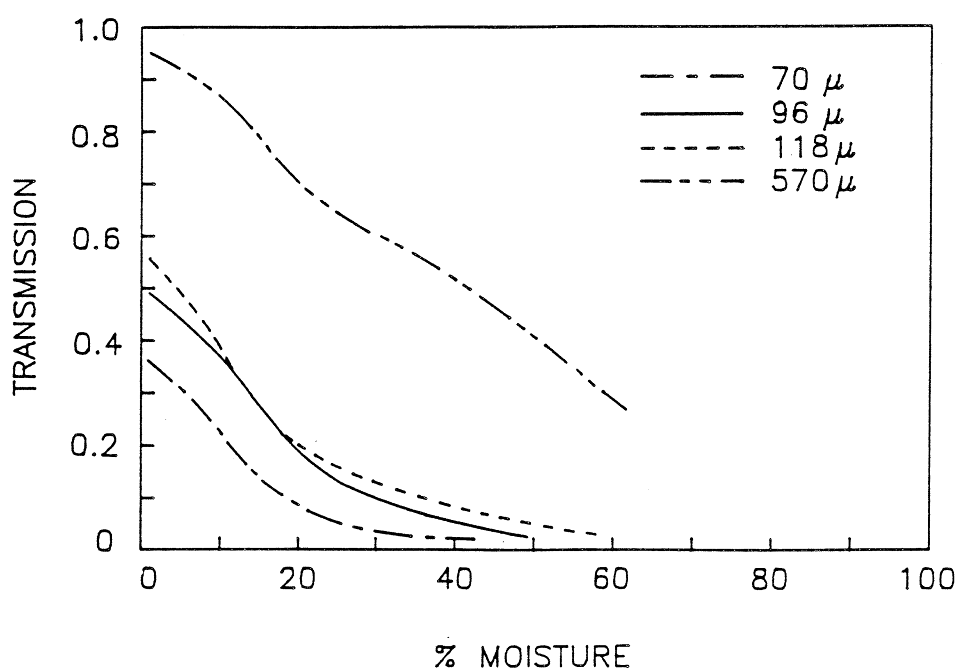
APPLICATIONS:

HIGH VOLTAGE CABLE INSPECTION

PAPER MAKING

PAPER MEASUREMENTS AT SUBMILLIMETER WAVE LENGTHS





TRANSMITTANCE OF 80 μM NEWSPRINT
AS A FUNCTION OF MOISTURE CONTENT

FROM BOULAY, ET AL., IR & MM WAVES, VOL. 5, PP 1221–1234, 1984

CONCLUSIONS

APPLICATIONS OF COHERENT SYSTEMS IN TERAHERTZ RANGE ARE EXTREMELY DIVERSE AND ARE EXPANDING

RAPID TECHNICAL PROGRESS IS TAKING PLACE ON MANY FRONTS

TRANS – MILLIMETER REGION IS NOW SIMILAR TO MILLIMETER RANGE JUST A FEW YEARS AGO AND $\lambda \leq 3$ MM RANGE IS COMPARABLE TO MICROWAVE REGION IN RECENT PAST

REAL SUBMILLIMETER REGION STILL HAS MANY CHALLENGES INCLUDING BASIC QUASIOPTICAL COMPONENTS, FREQUENCY SOURCES, ANTENNAS (INCLUDING ARRAYS) AND HIGH EFFICIENCY AND RUGGED MIXERS AND DETECTORS

AN IMPORTANT CONSIDERATION: **DIFFERENT APPLICATIONS HAVE ENORMOUSLY DIVERSE REQUIREMENTS**

THE SINGLE GREATEST OBSTACLE TO BROADER COMMERCIAL AND INDUSTRIAL UTILIZATION OF TERAHERTZ REGION IS **COST**

WE NEED TO MAKE IT CHEAP AS WELL AS GOOD !

I WOULD LIKE TO ACKNOWLEDGE CONSIDERABLE ASSISTANCE FROM J. BIRCH, P. EFTHIMION, R. GILES, D. KEAVENEY, R. MCINTOSH, E. MOORE, A. PARRISH, P. SIEGEL, J. WATERS AND OTHER CO–WORKERS AT MILLITECH AND AT F. C. R. A. O.