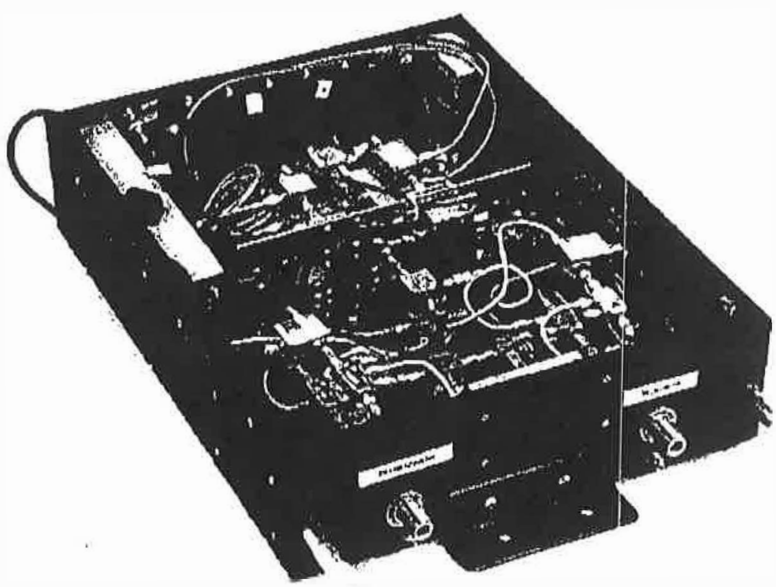
Original – Changed in Miami

C BAND SCATTEROMETER



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C-BAND WAVETANK SCATTEROMETER

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A coherent, continuous wave, dual linear polarized microwave scatterometer was designed and constructed for the University of Miami RSMAS wind-wave tank. The design was strongly influenced by the width of the tank (about 20 microwavelengths) and the limited overhead space. The system consists of a 60 cm parabolic antenna, an electronics module, and interconnecting cables. A single antenna was used to transmit and receive both horizontal and vertical polarization. Isolation between channels was achieved by using two slightly different frequencies, 5760 MHz and 5820 MHz for vertical and horizontal respectively. This also allows the transmitter for one polarization to be used as the local oscillator for the other. The return signal was beat down to base band through two stages and quadrature detected.

Photographs of the system are given in Figure 1 and a schematic of the electronic module in Figure 2. For each oscillator (#1), a power splitter (#2) is used to provide three outputs. Outputs from both oscillators are mixed to generate a 60 MHz signal, which is used as the intermediate frequency (IF) local oscillator. The second output is used as a transmitter and the third as the RF local oscillator for the opposite polarization. The transmitted signal enters port I of the circulator (#5) and exits port II; from there it is radiated by the antenna. The backscattered signal from the wind-disturbed water surface is passed through the circulator, into port II and out port III, on a path to the RF mixer (# 12). The IF signal from the mixer is amplified (#13), beat down to base band, and quadrature detected (#16 and 17). The electronic module has two type N connectors (#6) for attaching the antenna and seven BNC connectors. Two of these are for monitoring the IF signals (#15) and four are the inphase and quadrature outputs of the horizontal and vertical channels (#19). The remaining one is a reference channel output.

At low wind speeds the signal reflected from the water surface can be as much as six orders of magnitude below the transmitted power, while microwave circulators and other components usually reflect signals that are down only one or two orders of magnitude. Since the signal from the water surface is shifted in frequency, the two signals can be separated. However the larger unwanted signal can saturate the amplifiers. This problem is overcome by injecting a third signal of equal amplitude and 180 degrees phase difference through components #3,7,8,9 and 10. To achieve this the IF signal (# 15) is monitored with an oscilloscope or a detector and voltmeter. The variable phase shifter and attenuator (#8 and 9) are then adjusted to minimize the unwanted signal. If necessary the fixed phase adjuster (#7) can be removed to keep the phase shifter near the center of its range.

The IF local oscillator is generated by an RF mixer (#21) and amplified (#22). A six way power splitter (#24) is used to feed this signal to the L port of five IF mixers. A portion

Tank cal: max V = 5.87 V^2 max H = 4.39
A_V = 125 cm^2 A_H = 124 cm
C_V = 9.2×10^{-8} C_V = 1.24×10

of this signal is also fed to the R port of one of the IF mixers. Any change in the gain or transmitted power of the horizontal channel is reflected in this reference signal. Figure 3 is a detailed schematic of the base band amplifiers (#19 Figure 2). Four channels are AC coupled with a 3 dB passband of one Hertz to 1.4 kHz and a DIP switch for DC coupling. The reference channel has only DC coupling.

In order to illuminate only the center portion of the one meter wide tank, a custom antenna was used with the beam focused at 1.8 meters rather than infinity. The illumination patterns shown in Figures 4 (vertical) and 5 (horizontal) have well defined Gaussian shaped main beams with moderate sidelobes. These patterns were measured at an incidence angle of 41° and a range of 1.83 meters. The beamwidth, which is small compared to the size of the tank, can be adjusted a small amount by changing the range. For large changes in range a different feed must be used. A spare feed was supplied for ranges greater than six meters. For ranges between two and six meters the feed must be modified using the copper tube also supplied.

The above patterns were generated by measuring the backscattered power from a metal coated ping pong ball moving on a treadmill in the plane of incidence. The radar cross section for metal spheres is shown in Figure 6. The radius of the ping pong ball was 1.9 cm and the transmitted wavelengths were 5.15 cm for horizontal and 5.21 cm for vertical. The value of the circumference divided by the wavelength was 2.3, which is at the peak of the second resonance. The calibration treadmill was furnished with the system. A one amp 125 volt fuse is located inside the electronic module.

To calibrate the system to produce normalized radar cross sections, the following equation is used:

$$\sigma_o = \frac{C\rho R^4}{A} \tag{1}$$

where C is a calibration constant, R is range to the surface, A is illuminated area, and ρ is the sum of the squares of the inphase and quadrature signals out of the system. The latter quantity may be normalized by the square of the reference signal if desired to guard against gain changes in the system. The area, A, is the integral over the patterns shown in Figures 4 and 5. To a good approximation, this is given by

A_V = 222 cm
A_H = 257 cm

$A = 34850.8\, \Phi^2$

$$A = \frac{\pi}{4}\frac{\Phi^2 R^2}{\cos \theta_i} \qquad \text{effective } \Phi = \frac{\sqrt{A}}{186.7}\frac{180}{\pi} = .3\sqrt{A} \tag{2}$$

where θ_i is the incidence angle and Φ is ~~the~~ an equivalent one-way, half-power, full beamwidth of the antenna. The measured areas are consistent with $\Phi_V = \cancel{5.7}°$, yielding an illuminated surface areas of $A_V = \cancel{\pi(5)(7)}\ 222\ \cancel{110}$ cm^2; A_H = 257 cm^2 effective 4.5 Φ_H = 4.8°

spot size
V: 14.4 cm
19 cm
H: 15.1
20.7

The calibration constant is determined from the maximum power returned from the ping pong ball using the following equation:

$$C = \frac{\sigma_c}{\rho_c R_c^4} \tag{3}$$

where R_c is the range during calibration, ρ_c is the maximum power (normalized, if desired) from the ping pong ball, and σ_c is the cross section of the ping pong ball from Figure 6. This

C_V = ~~4.1×10^{-7}~~ 4.76×10^{-8}

C_H = ~~2.9×10^{-6}~~ 6.39×10^{-8}

$P_V(max)$ = .1919 V^2
$P_H(max)$ = .6194 V^2

is $\sigma_c = 34.0$ cm^2. Calibrations performed in the University of Miami's wavetank at the time of installation gave

$$C = \tag{4}$$

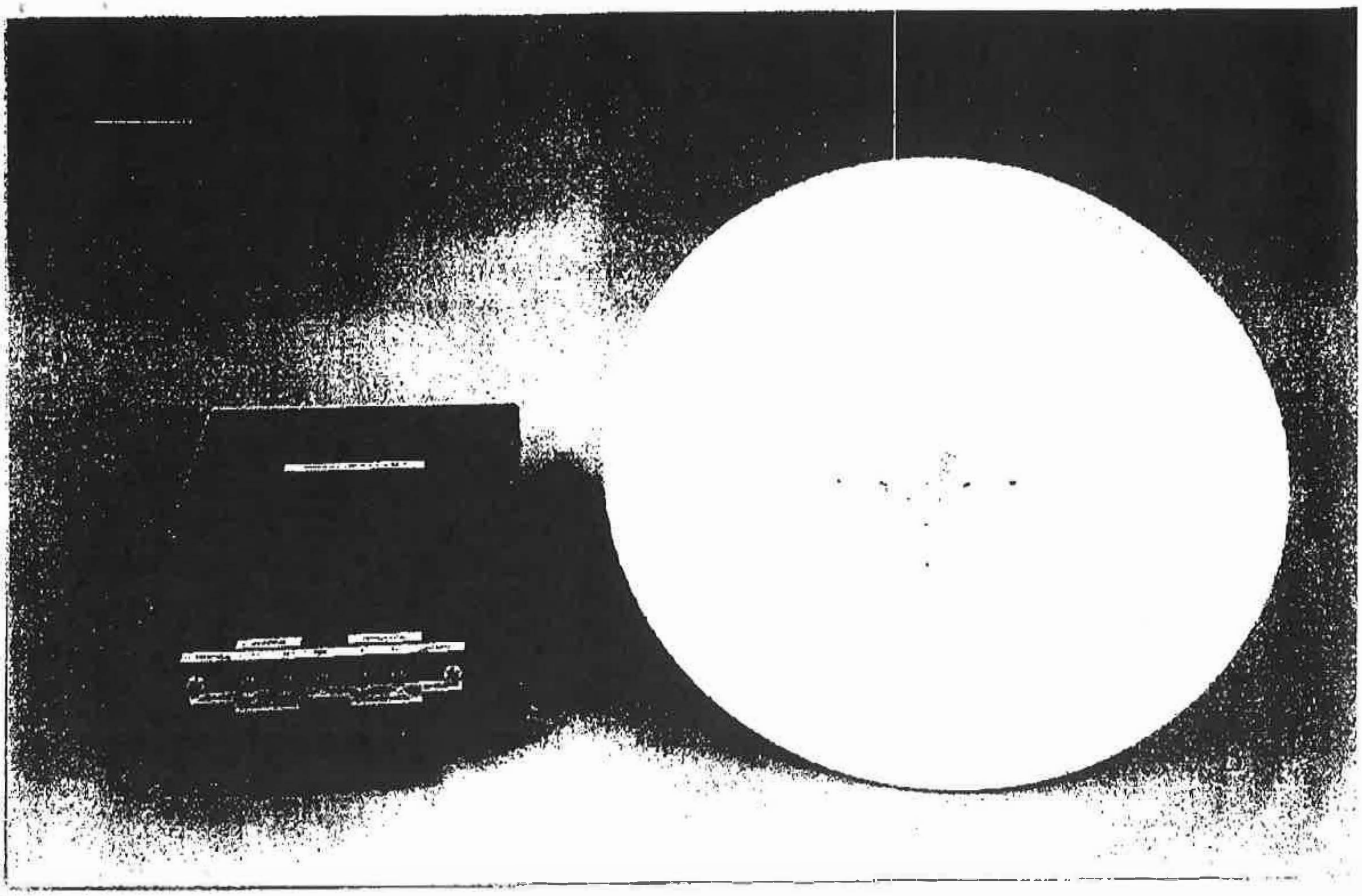
for vertical polarization and

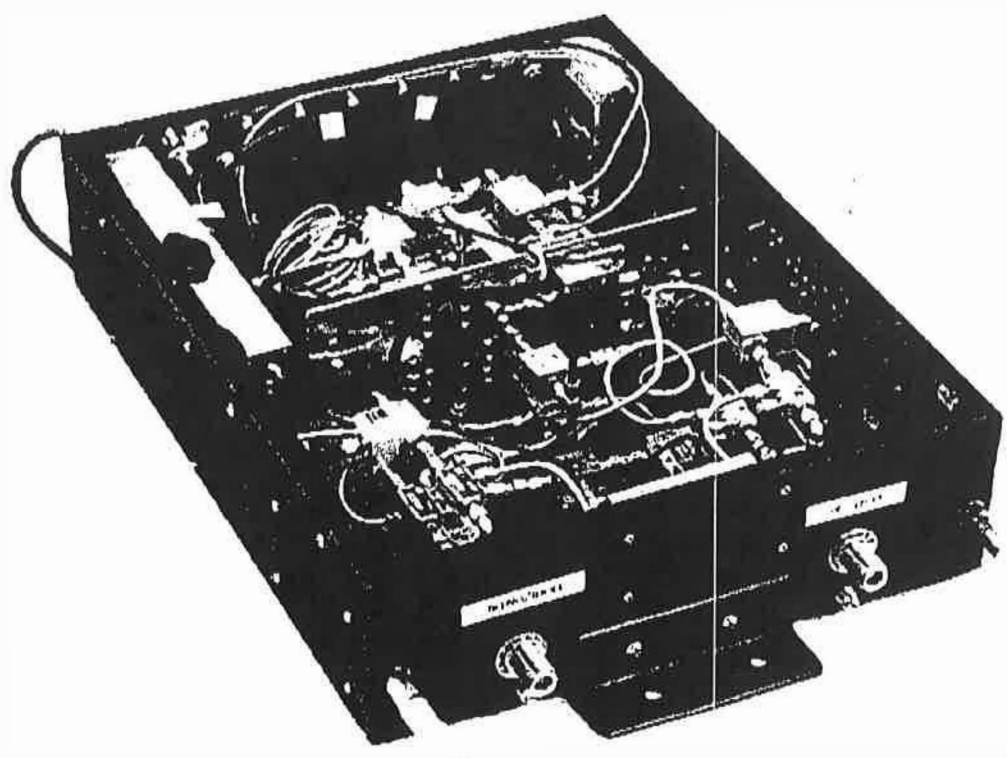
$$C = \tag{5}$$

for horizontal polarization.

FIGURE CAPTIONS

1. Photo of antenna and electronic module.
2. Schematic of microwave system.
3. Printed circuit board schematic
4. Vertical antenna pattern at a range of 1.83 meters and 41 degrees incidence.
5. Horizontal antenna pattern.
6. Radar cross section for conducting spheres where a is the radius, lambda the wavelength and sigma the radar cross section.





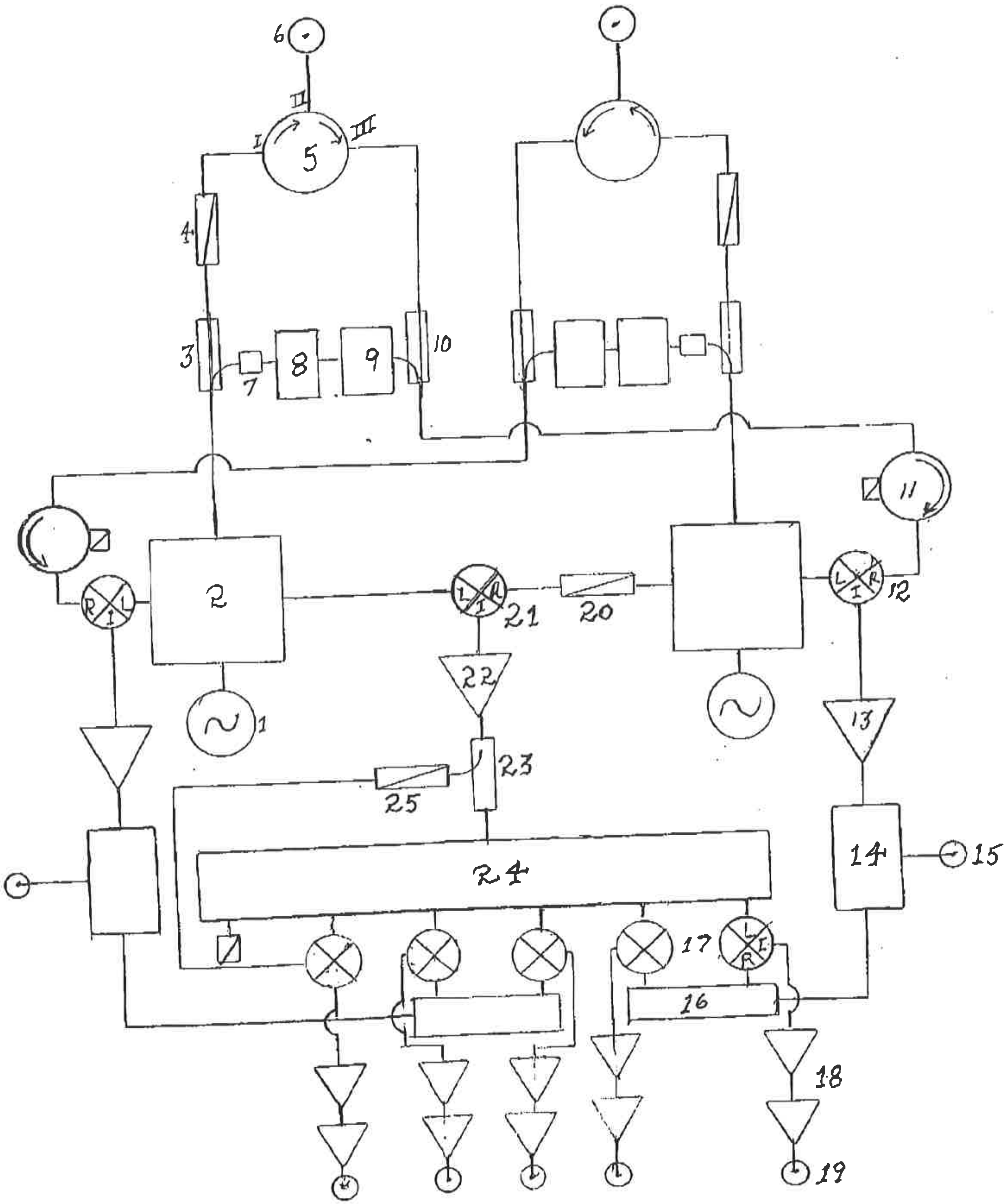
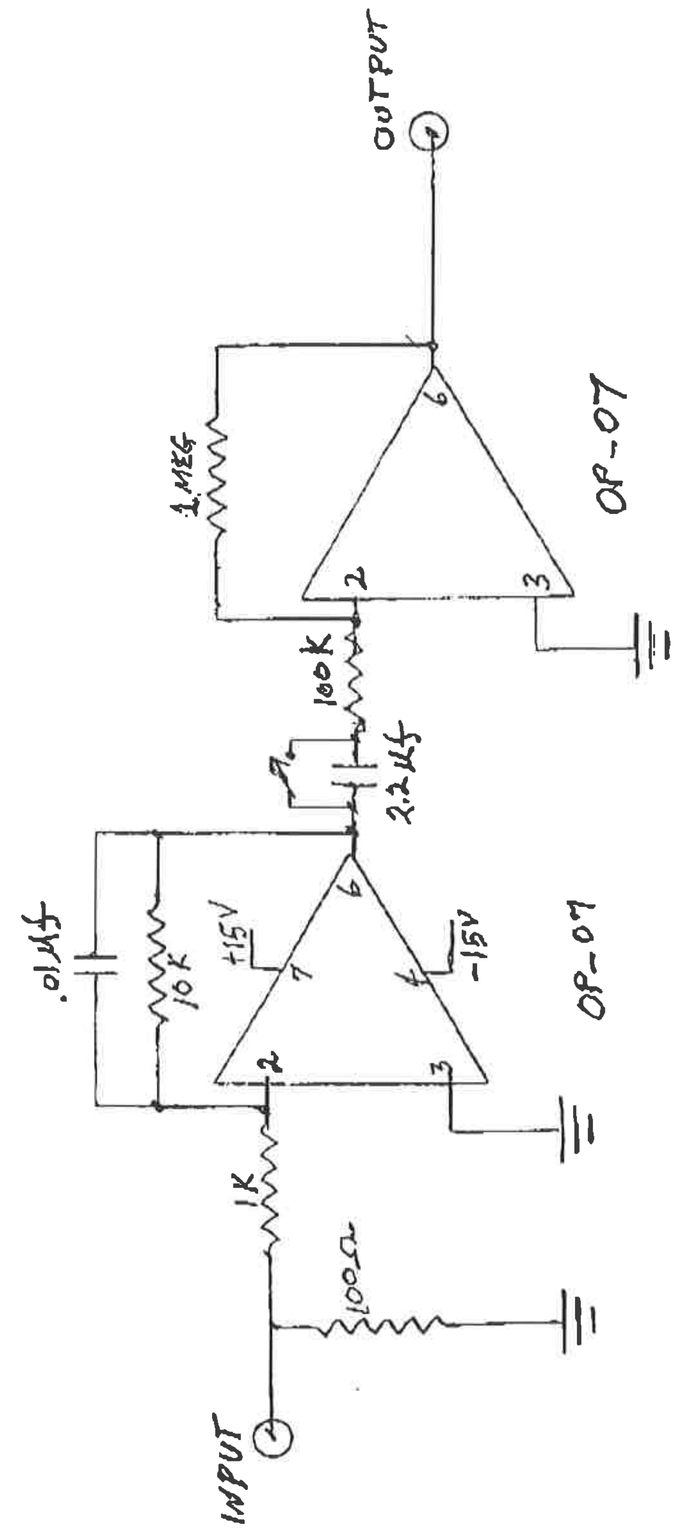
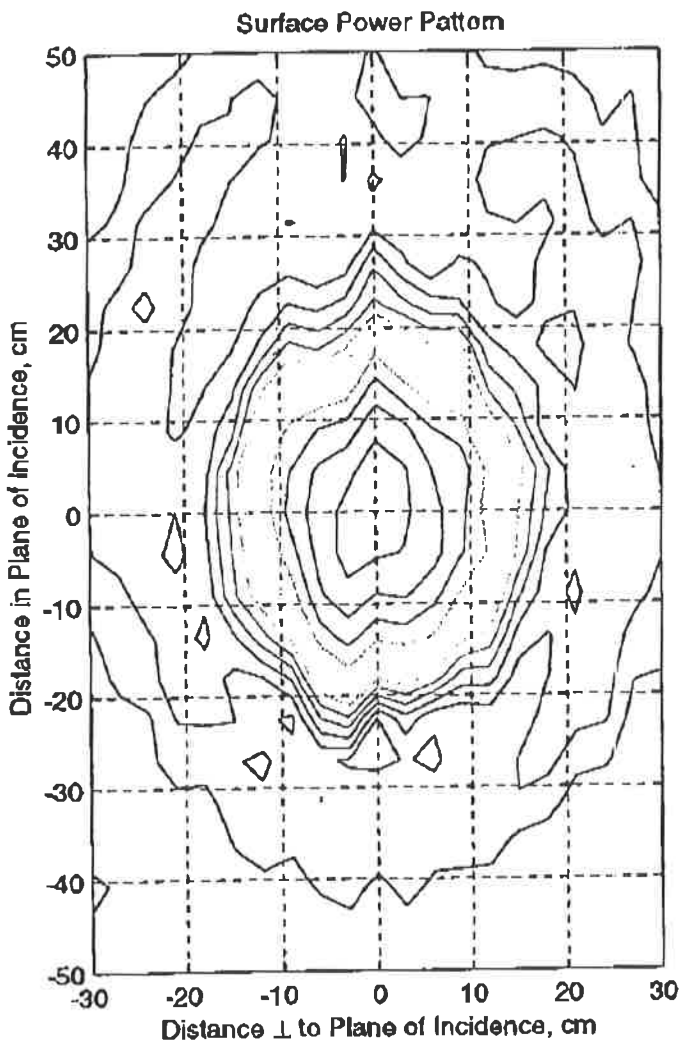

6
II
I
5
III
4
3
7
8
9
10
11
2
21
20
12
R I L
L I R
22
1
13
23
25
14
15
24
17
16
18
19

FIGURE 2

1 Microwave oscillator, Horizontal – 5820 MHz,
Vertical ---- 5760 MHz
2 Three way power splitter
3 Directional coupler
4 Attenuator, H= 2 dB, V = 3 dB
5 Circulator
6 Antenna port, type N female
7 Fixed phase adjuster
8 Variable phase shifter
9 Variable attenuator
10 Directional coupler
11 Isolator
12 RF Mixer
13 IF amplifier
14 Two way power splitter
15 IF monitor port, BNC female
16 Quadrature Hybrid
17 IF mixers
18 Base band amplifiers, on printed board
19 Output ports, BNC female
20 RF attenuator, 20 dB
21 RF mixer
22 Second LO amplifier
23 Directional coupler
24 Six way power splitter
25 IF attenuator, 20 dB


INPUT
100Ω
1K
.01μf
10K
+15V
-15V
OP-07
2.2μf
100K
1MEG
OP-07
OUTPUT

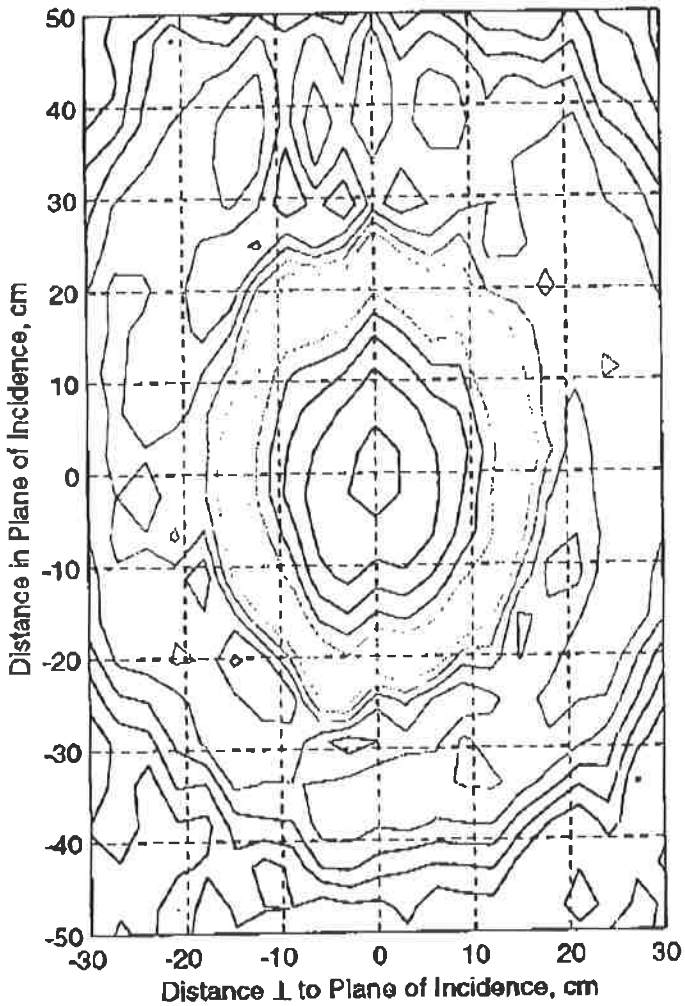


Vertical polarization

$R = 1.83$ m, $\theta_i = 41°$

Contour = 3 db

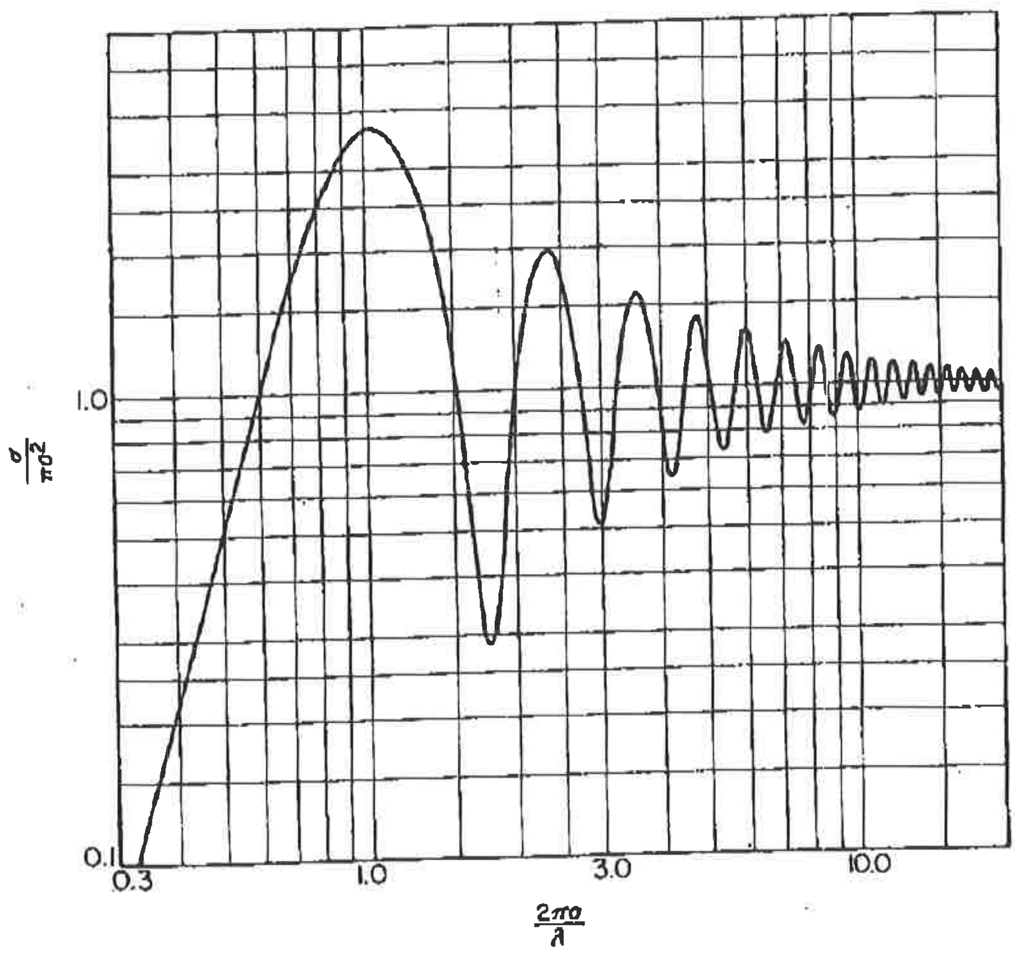
Surface Power Pattern



Horizontal polarization

R = 1.83 m, $\theta_i = 41°$

Contour = 3 db



Normalized cross section for conducting spheres.