15. seminar Radiokomunikacije 2008

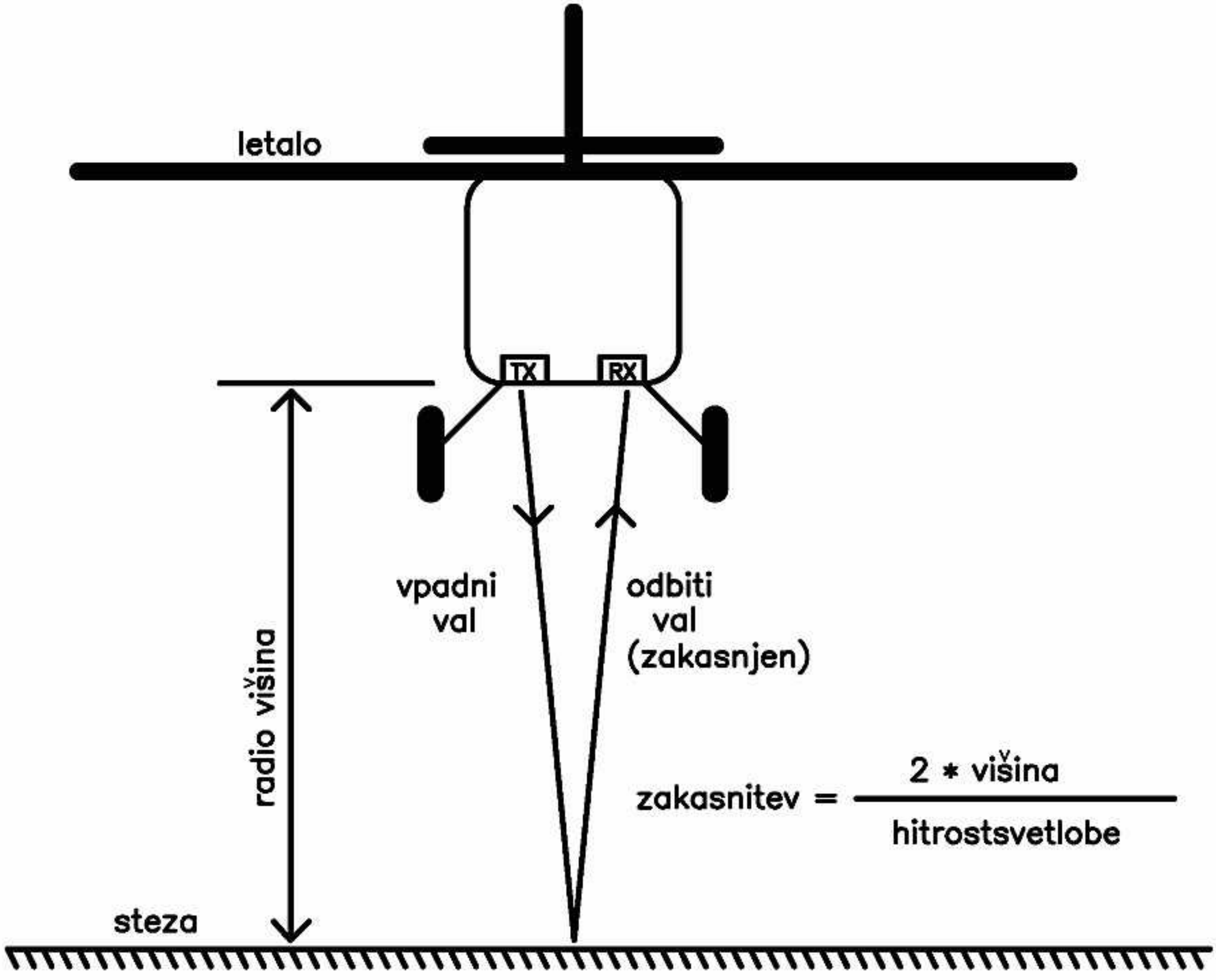
Letalski radarski višinomer

prof. dr. Matjaž Vidmar

Fakulteta za elektrotehniko

http://www.s5tech.net/s53mv/


S5-PCV
UL MOTORGLIDER
sinus


letalo
TX
RX
vpadni
val
odbiti
val
(zakasnjen)
radio višina
steza
zakasnitev = 2 * višina / hitrostsvetlobe

Funk-Höhenmesser FuG 101

Radio-Altimeter FuG 101

Reinecker Lehrfahrgerätewerk Hakenfelde GmbH, Berlin, 1941

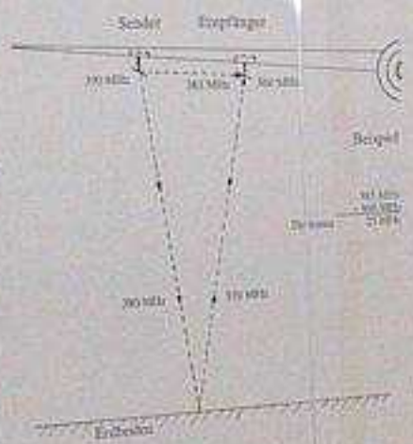
Funk-Höhenmesser (auch Radar-Höhenmesser genannt) messen nach dem Echolot-Prinzip die Höhe über Grund. Gerade bei Blindlandungen ist dieses Verfahren dem barometrischen Feinhöhenmesser überlegen, da bisherige Fehlerquellen (z.B. Druckeinstellung) wegfallen.

Das vom Lehrfahrgerätewerk Hakenfelde (Siemens) gebaute FuG 101 ging bereits 1941 in Serie.

Arbeitsweise

Der Höhenmesser besteht aus Sender, Empfänger und Anzeige. S[illegible] befinden sich meist [illegible] unter einer Tragfläche. An [illegible] externe wird ein Funksignal [illegible] periodisch veränderter Frequenz abgestrahlt. Es erreicht sowohl auf direktem Wege, als auch vom Erdboden reflektiert, die Empfangsantenne. Auf diese Weise gehen fast gleichzeitig zwei Signale mit unterschiedlichen Frequenzen ein. Je größer die Differenz dieser beiden Frequenzen, [illegible] desto länger ist die Laufzeit des reflektierten Signals, [illegible] und umso größer auch die Höhe über Grund. An einem geeichten Drehspulinstrument [illegible] wird dieser Wert als Höhe über Grund angezeigt. Die Meßgenauigkeit liegt bei ca 3 Meter.

Das FuG 101 wurde über 30.000 mal gebaut und von 1942 bis 45 in größeren deutschen Flugzeugen eingesetzt.



Funk-Höhenmesser (Empfänger)

Radio-Altimeter (Receiver)

Lehrfahrgerätewerk Hakenfelde GmbH, Berlin, 1941

Das Empfangsgerät E 101a der Anlage FuG 101a bildet eine Einheit mit der Dipol-Antenne unten. Der oben liegende 7-Röhren-Empfänger beinhaltet einen Frequenzzähler, der das Anzeigeinstrument ansteuert.

[illegible]

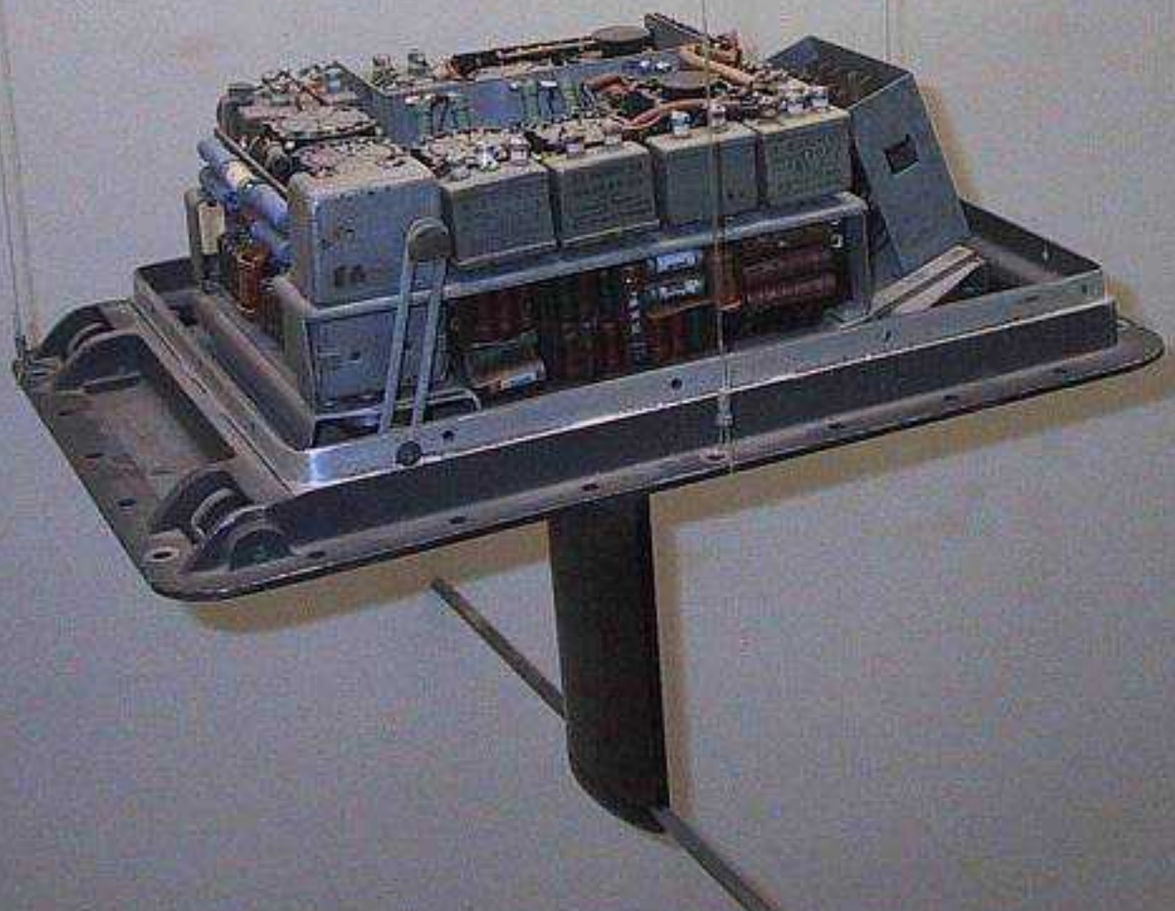
Funk-Höhenmesser (Sender)

Radio-Altimeter (Transmitter)

Lehrfahrgerätewerk Hakenfelde GmbH, Berlin, 1941

Sender S 101a mit Dipol-Antenne (Anlage FuG 101a). Ein Drehkondensator wird durch Elektromotor gedreht und damit die periodische Änderung der Frequenz erzeugt. Basisfrequenz 375 MHz, Leistung 1,5 Watt.

[illegible]



Funk-Höhenmesser (Anzeigegerät)

[illegible]

Funk-Höhenmesser (Anzeigegerät)

Radio-Altimeter (Indicator)

Luftfahrtgerätewerk Hakenfelde GmbH, Berlin, 1943

Umschaltbares Drehspulinstrument der FuG 101a-Anlage
zur Anzeige von zwei Höhenbereichen: 0-150m und 0-750m.
Durch Ziehen des Eichknopfes kann das Gerät
auch im Fluge nachjustiert werden (Eichsignal: 60m).

Stifter: Siemens und Halske A.G., Karlsruhe

Inv.Nr.: 74030,3

Department of Transportation
Federal Aviation Administration
Aircraft Certification Service
Washington, DC

TSO-C87

Date: 2/1/66

Februar 1966!!!

Technical Standard Order

Subject: TSO-C87, AIRBORNE LOW-RANGE RADIO ALTIMETER

TITLE 14–AERONAUTICS AND SPACE

Chapter 1–Federal Aviation Agency [Docket No. 6545; Amendment 37-4]

PART 37–TECHNICAL STANDARD ORDER

Airborne Low-Range Radio Altimeter Equipment

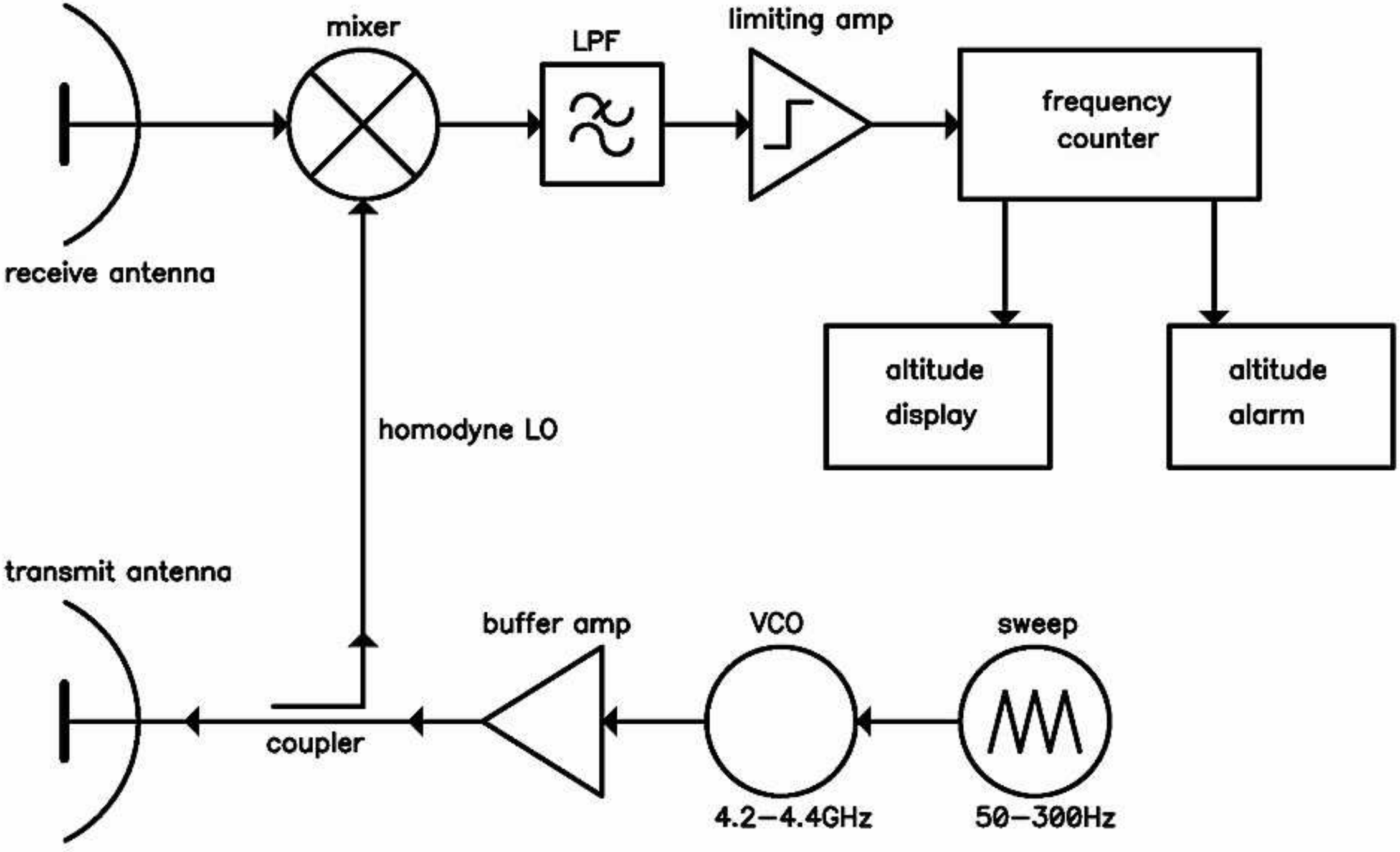
The purpose of this amendment is to add a new

ments are those contained in the notice.

In connection with the foregoing, comments were received pointing out certain problems which would be encountered in demonstrating the accuracy for radio-altimeters in-flight measurements must be made, a relaxation of the in-flight accuracy requirements was

tion of direct measurement data from laboratory tests, supplemented by appropriate in-flight measurements, calculations and extrapolations where it is no practical to obtain direct measurements. It was intended in the proposal to permit the use of other methods and laboratory test procedures in meeting the standard. The Agency,

Ajaccio APP
121.05MHz


mixer
LPF
limiting amp
frequency counter
receive antenna
altitude display
altitude alarm
homodyne LO
transmit antenna
buffer amp
VCO
sweep
coupler
4.2–4.4GHz
50–300Hz

končno približevanje

prekinjajoč ton
perioda se veča

ravnanje

stalen pisk
višina tona upada

bip–bip–bip

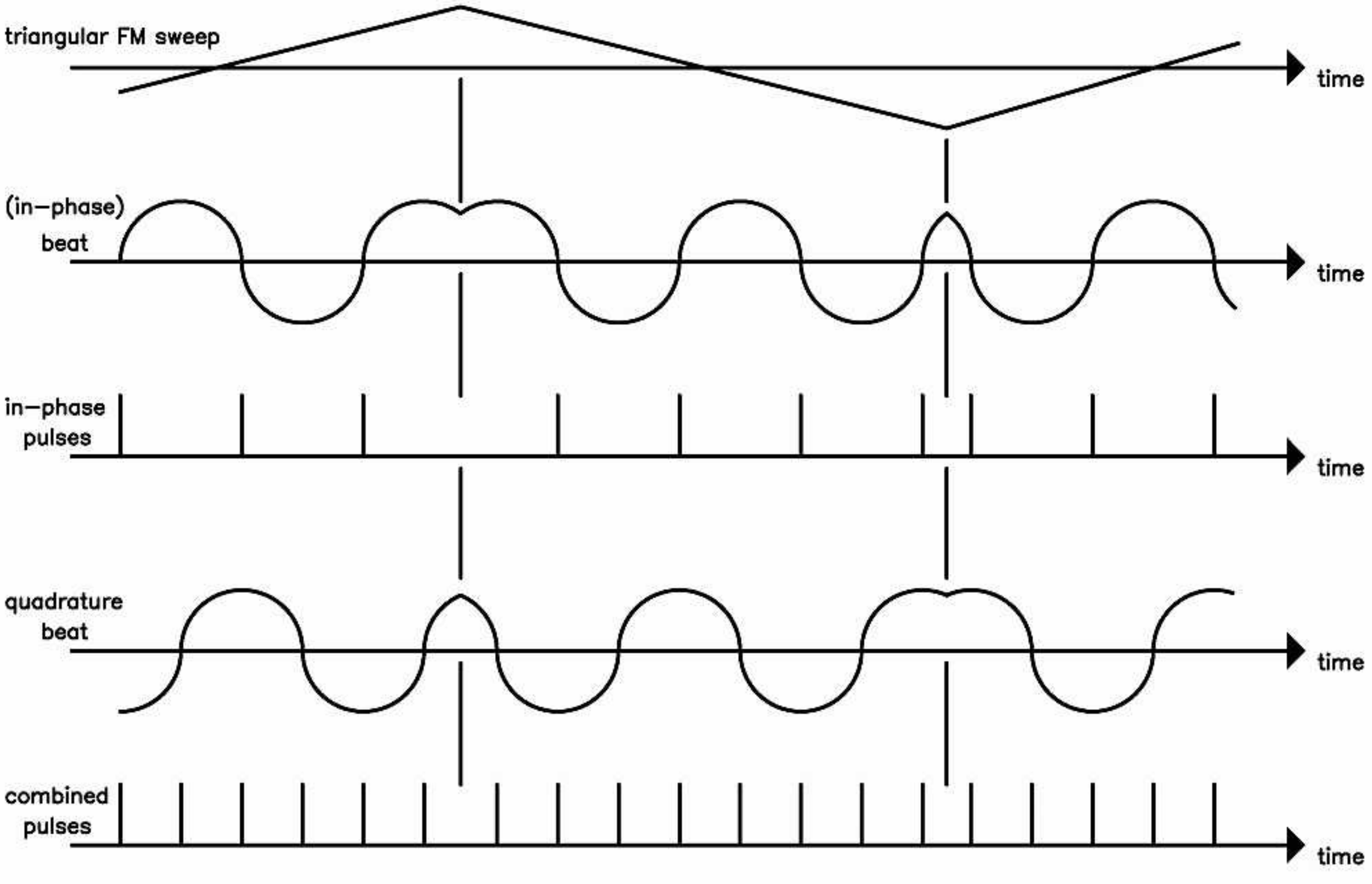
biiiiip–biiiiip

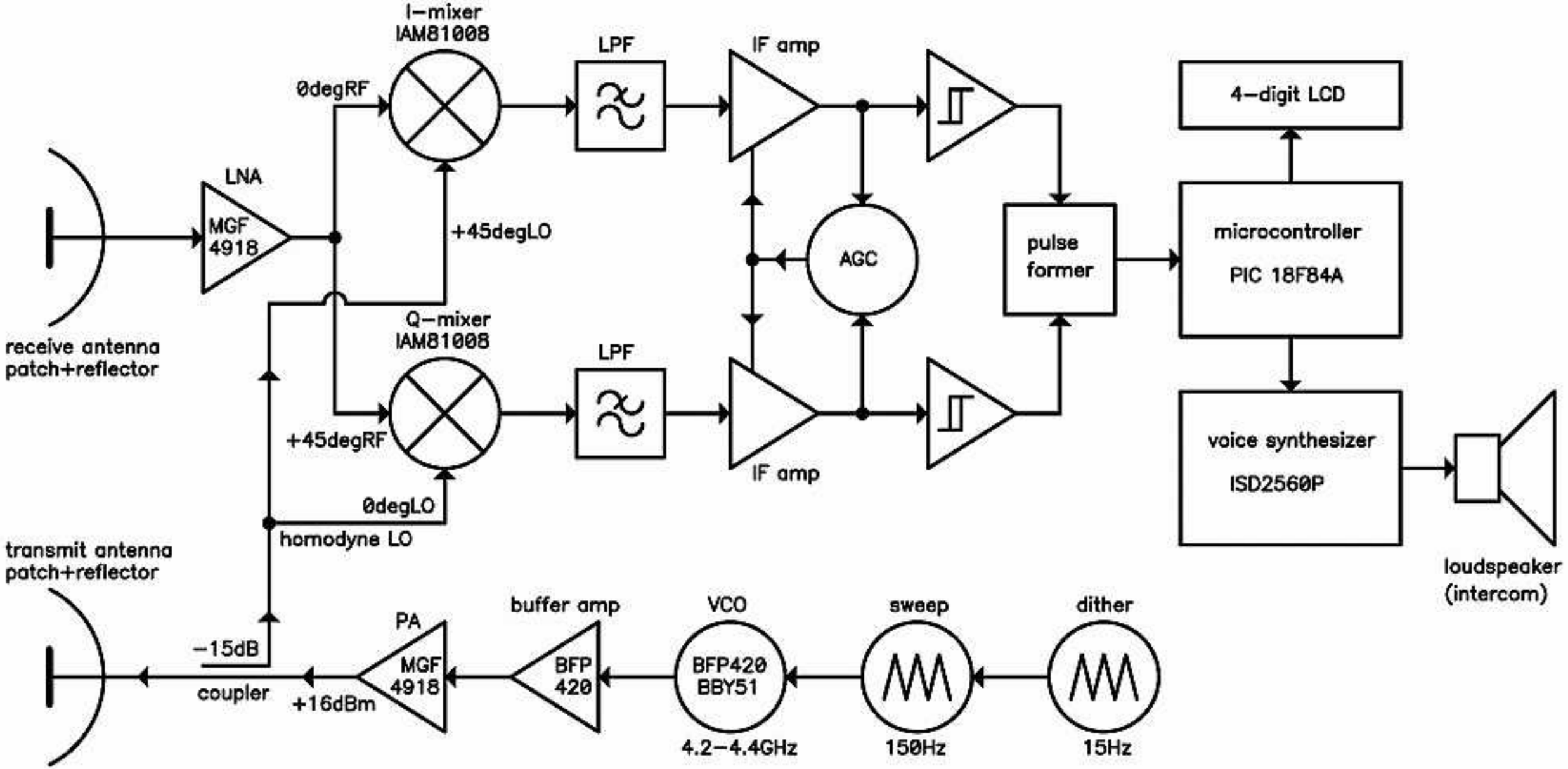
biiiiiiiiiiiiii

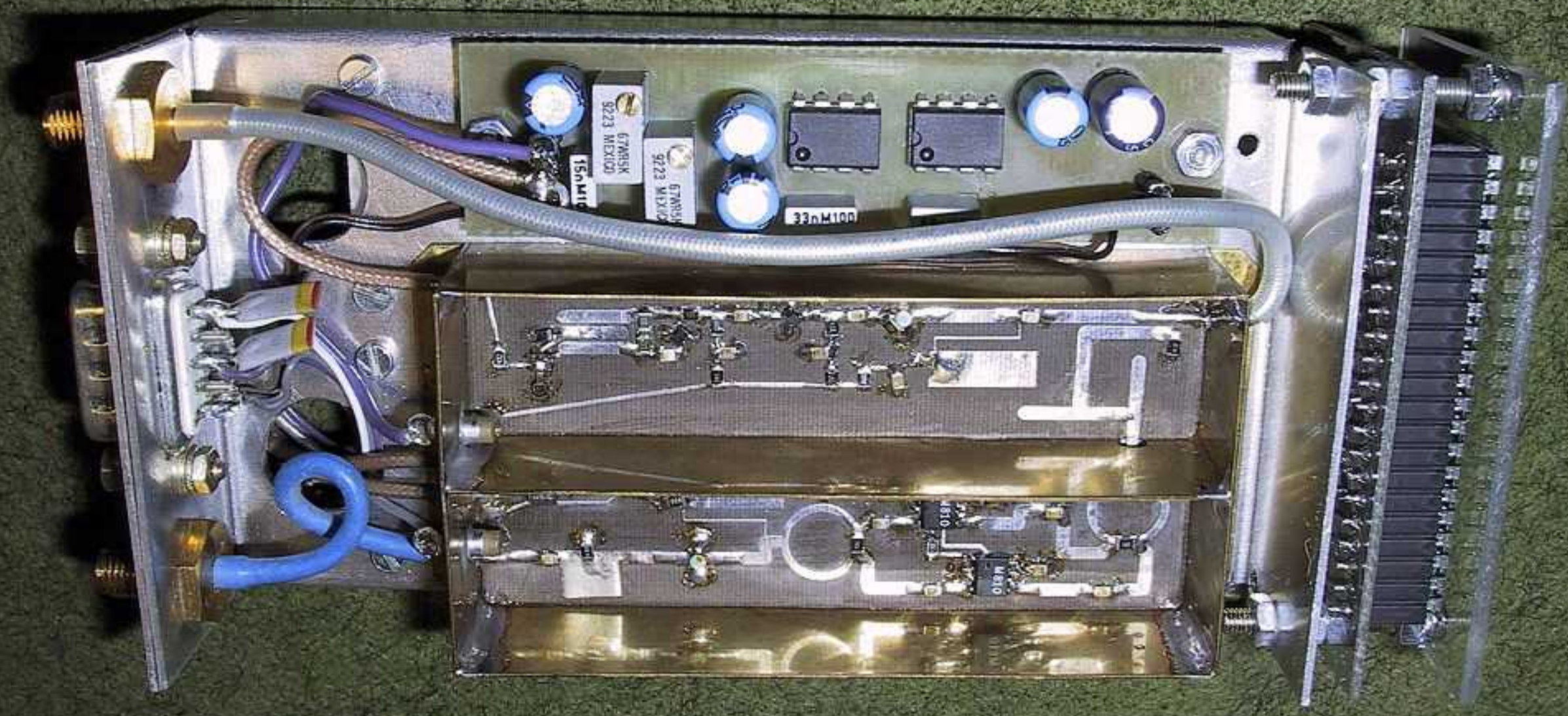
tirnica letala

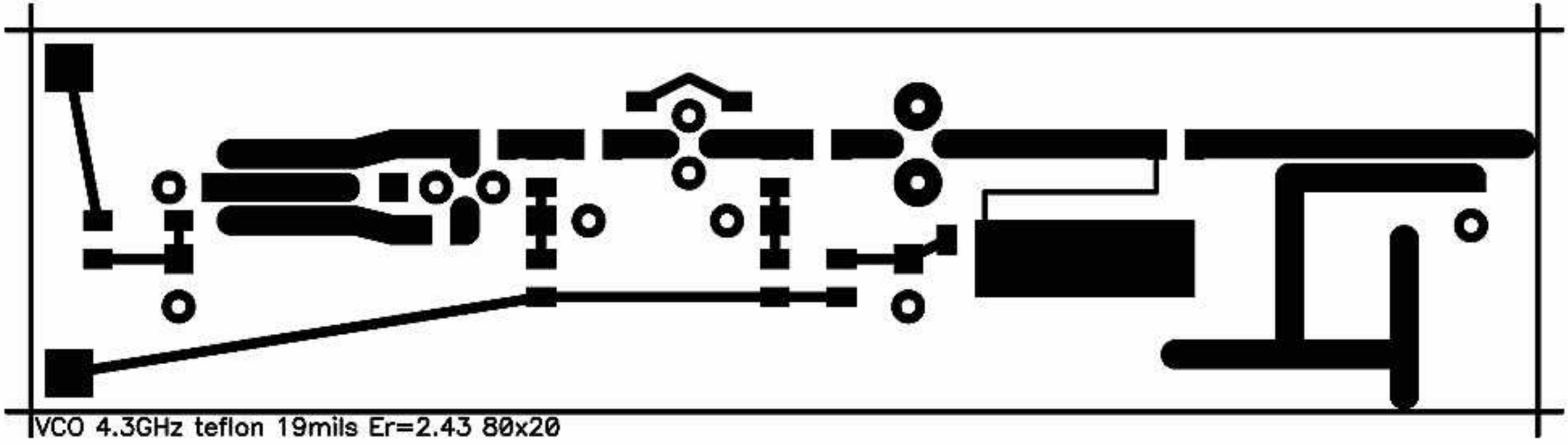
booooooooooo

steza

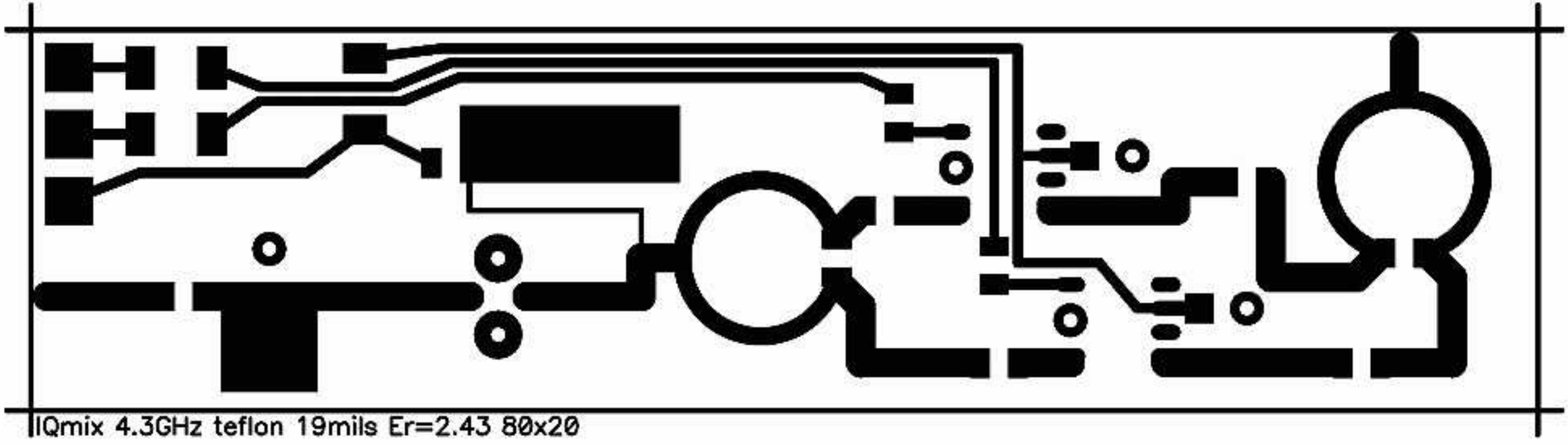

triangular FM sweep
time
(in–phase)
beat
time
in–phase
pulses
time
quadrature
beat
time
combined
pulses
time


I–mixer
IAM81008
LPF
IF amp
0degRF
4–digit LCD
LNA
MGF
4918
+45degLO
AGC
pulse
former
microcontroller
PIC 18F84A
receive antenna
patch+reflector
Q–mixer
IAM81008
LPF
+45degRF
IF amp
0degLO
homodyne LO
voice synthesizer
ISD2560P
loudspeaker
(intercom)
transmit antenna
patch+reflector
buffer amp
VCO
sweep
dither
PA
–15dB
MGF
4918
BFP
420
BFP420
BBY51
coupler
+16dBm
4.2–4.4GHz
150Hz
15Hz

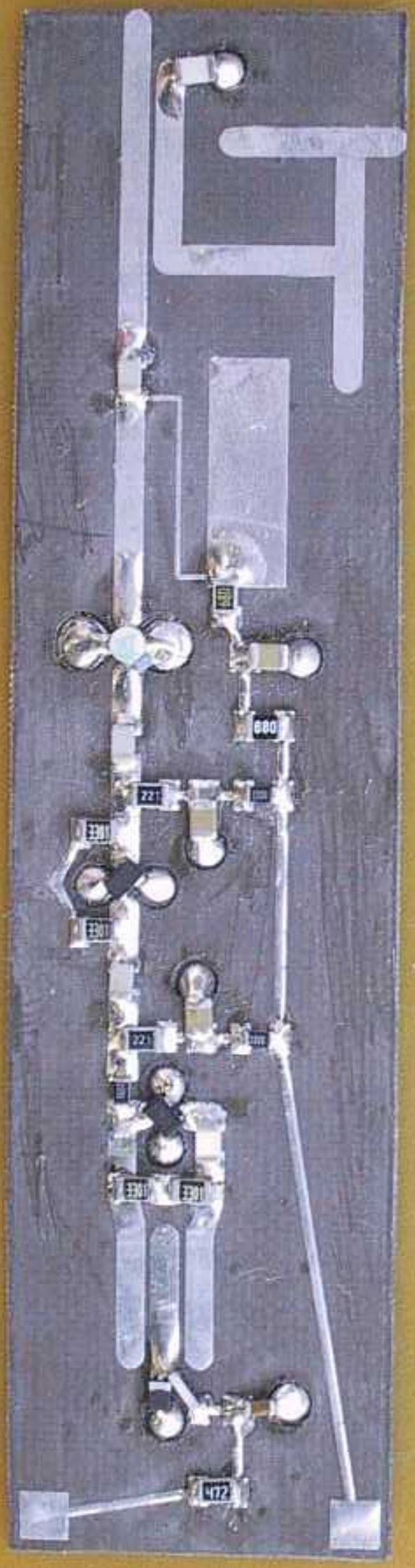

33nM100



VCO 4.3GHz teflon 19mils Er=2.43 80x20

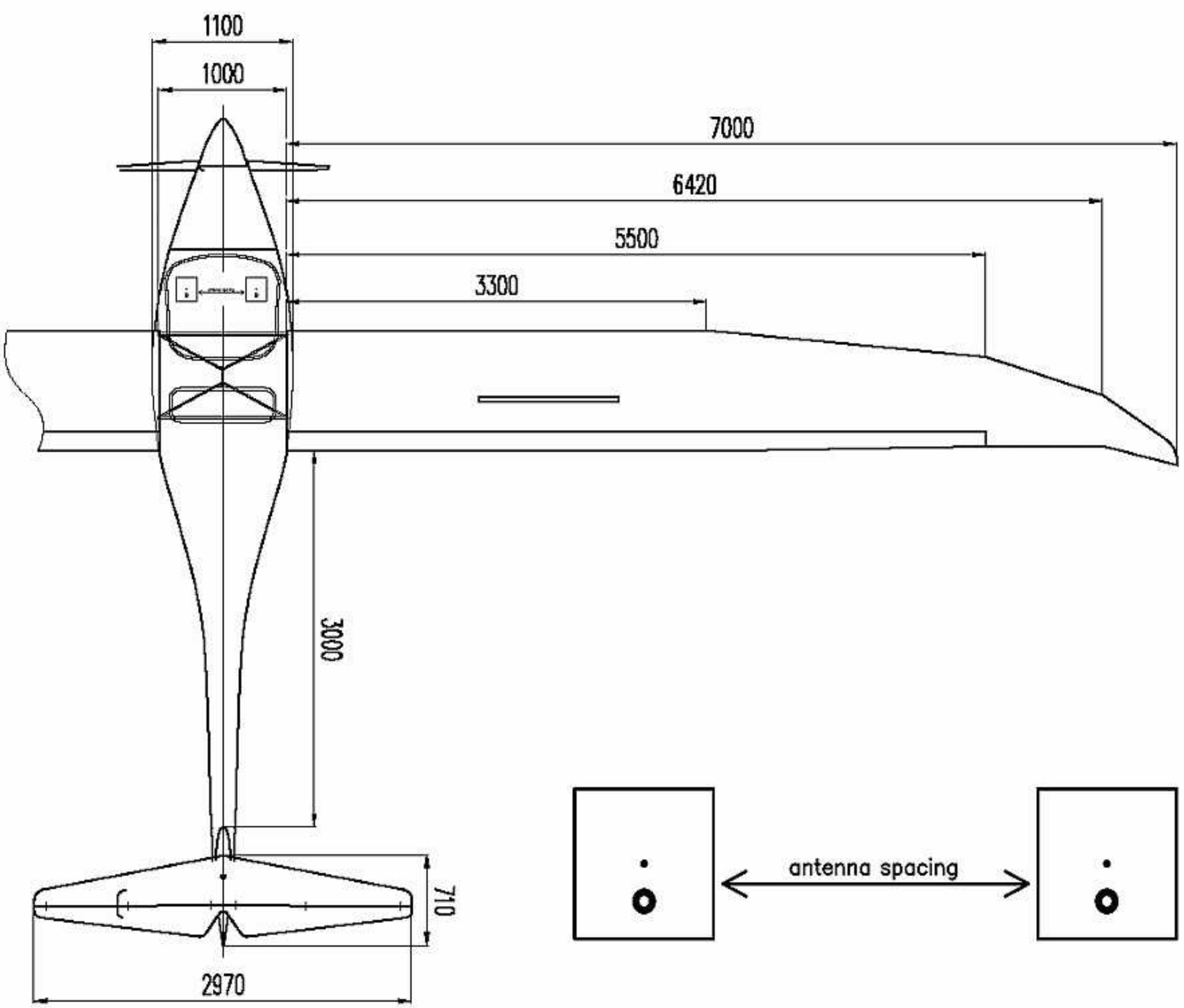


IQmix 4.3GHz teflon 19mils Er=2.43 80x20

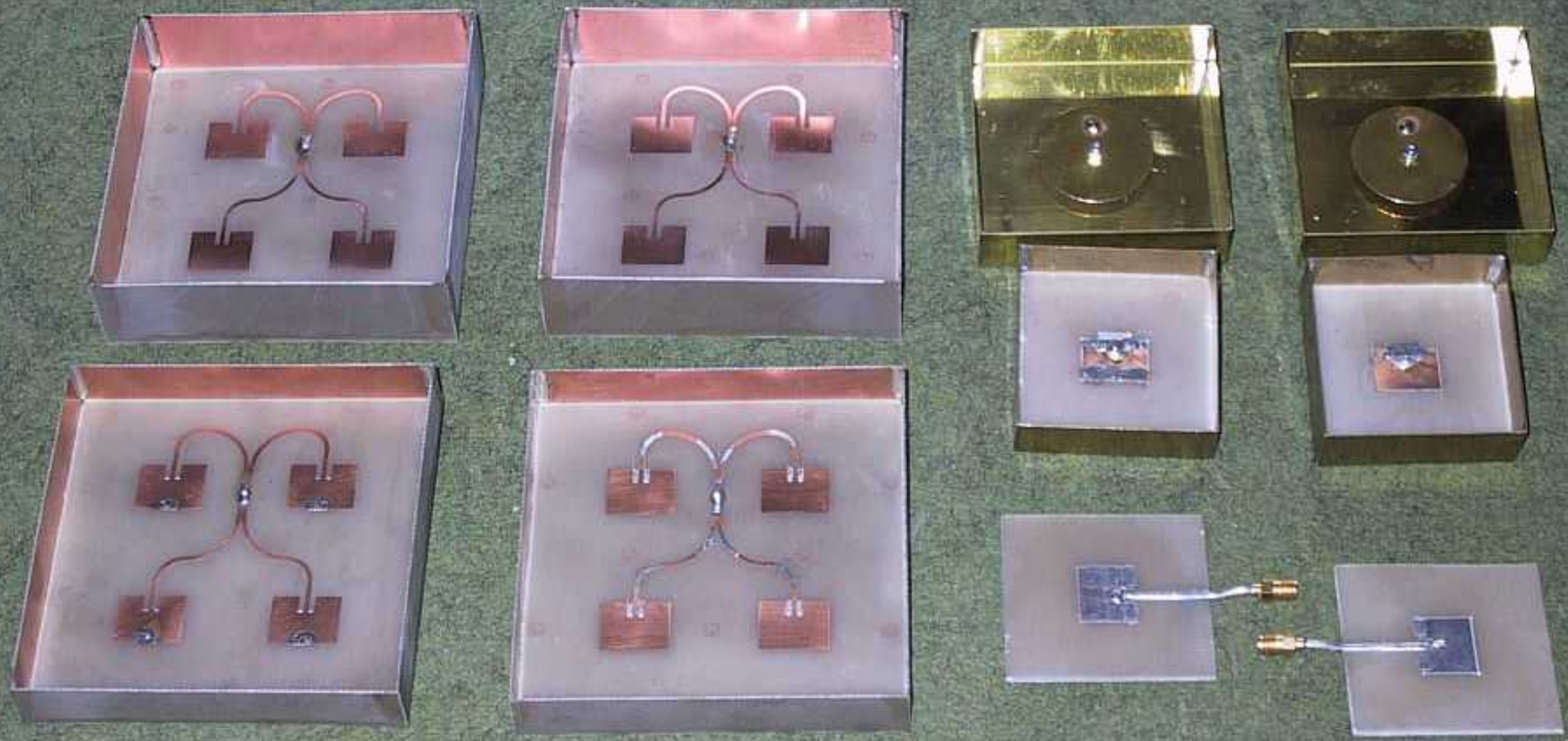

680
221
221
472

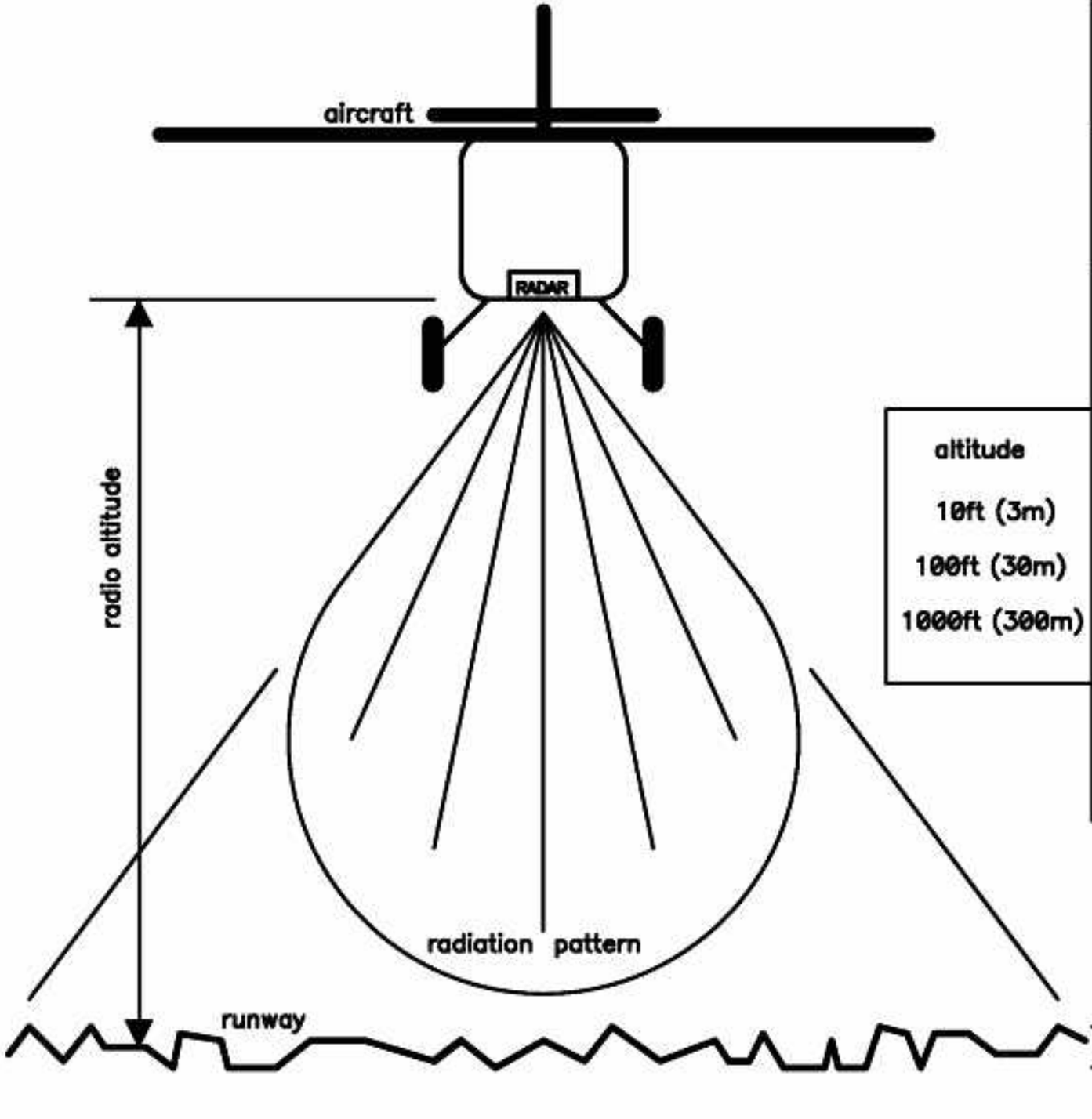

M810
M810
330
330
R10
330
330


AGC
PULSE
2560P
0406
H3537407


1100
1000
7000
6420
5500
3300
3000
710
2970

antenna spacing

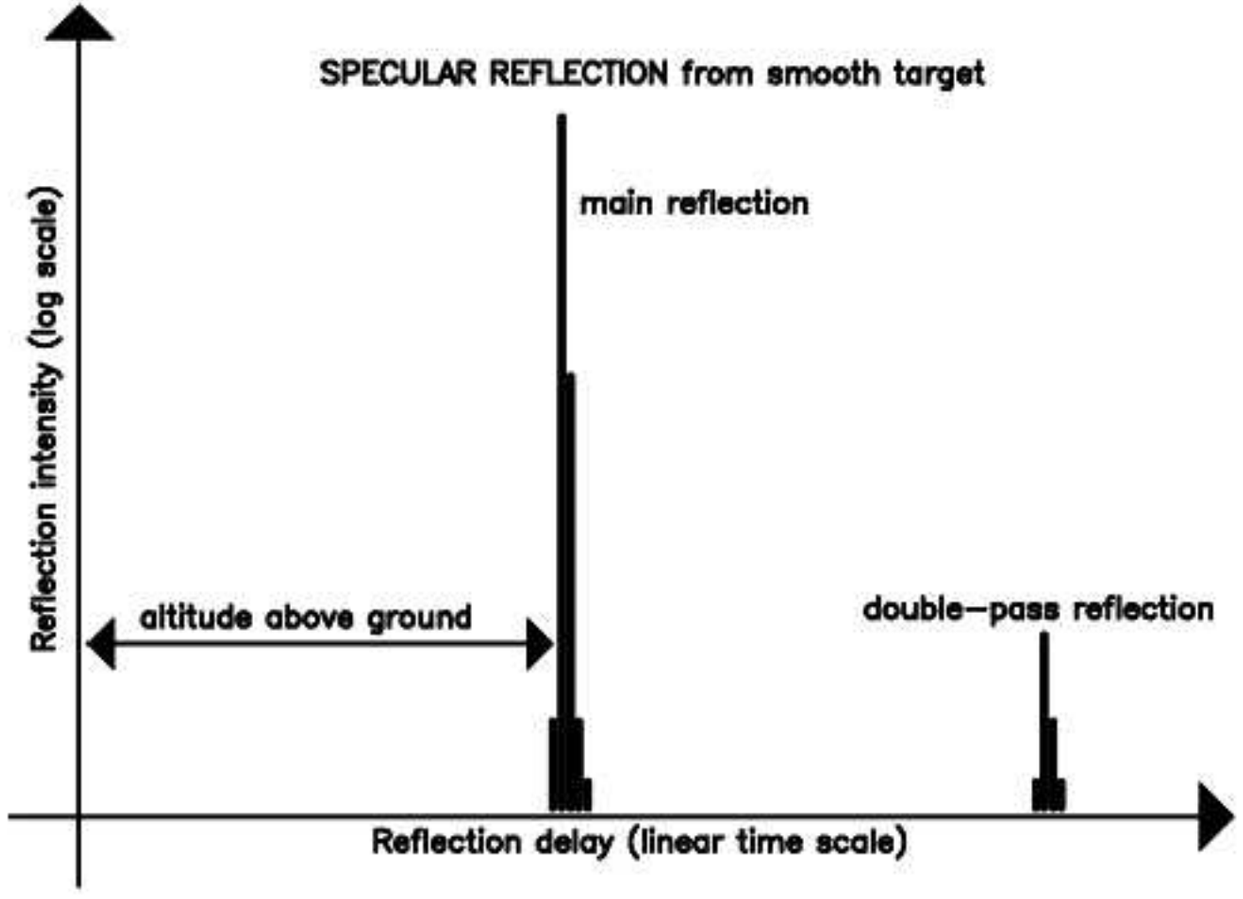


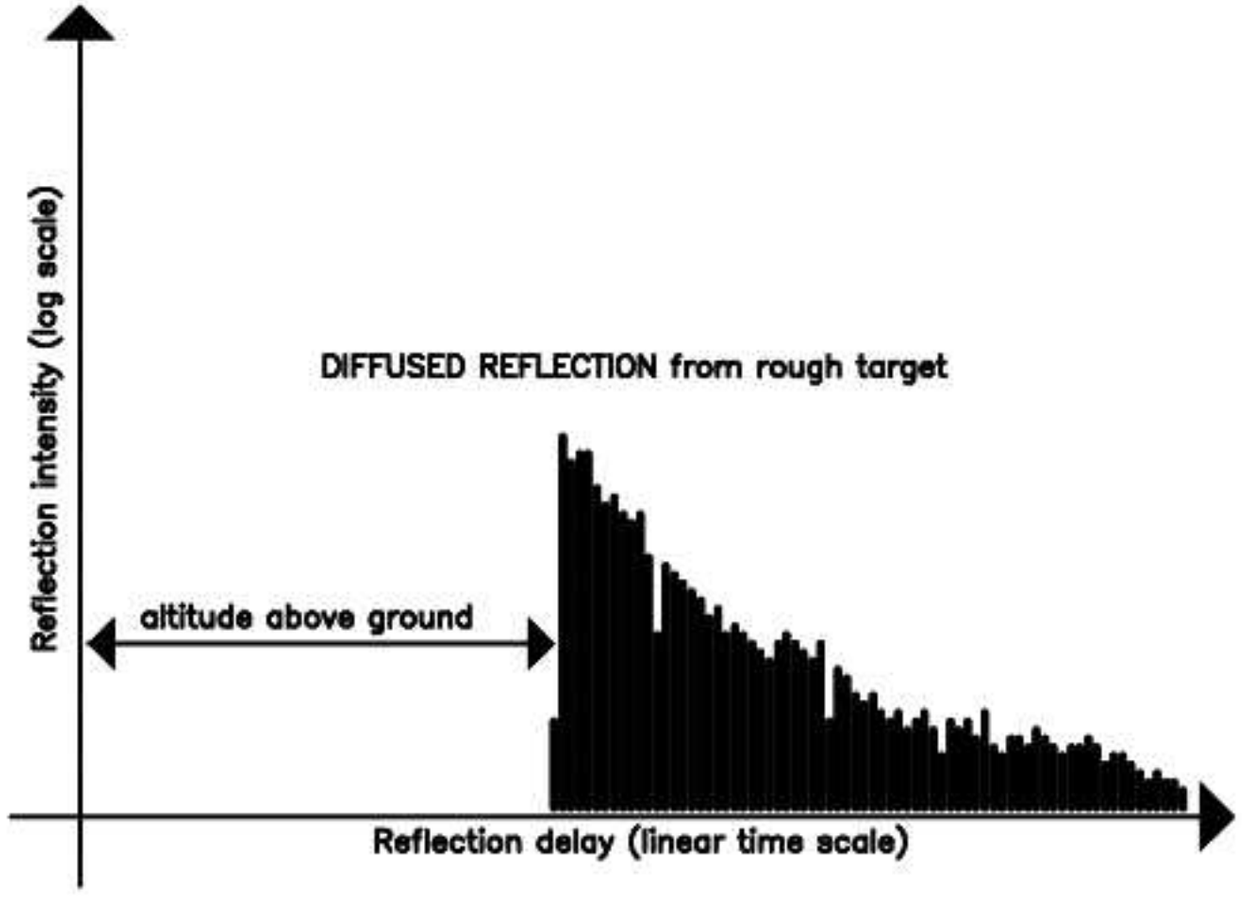


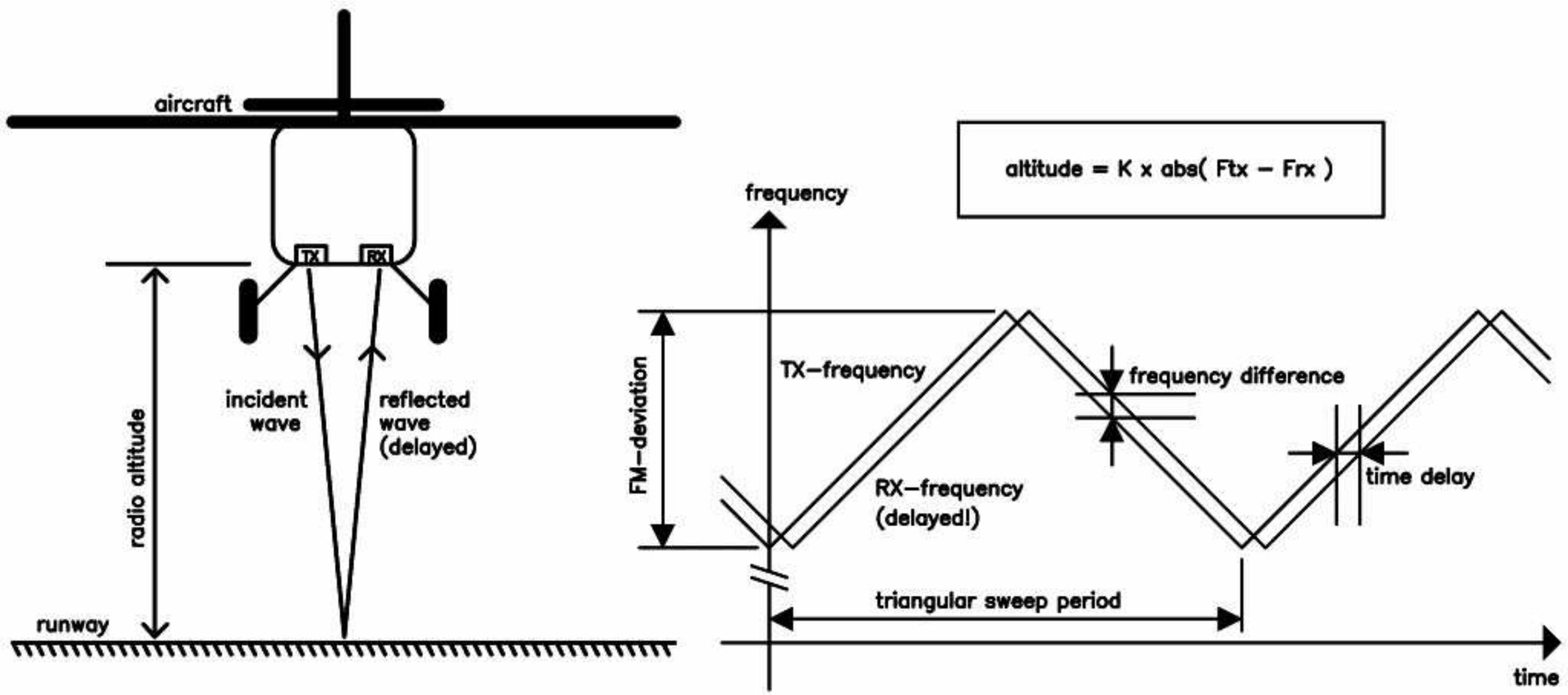
roughness << wavelength	roughness >> wavelength
SPECULAR reflection	DIFFUSED reflection
reflection area defined by first Fresnel zone	reflection area defined by antenna radiation pattern
strong reflected signal	weak reflected signal
steady signal level	random signal level

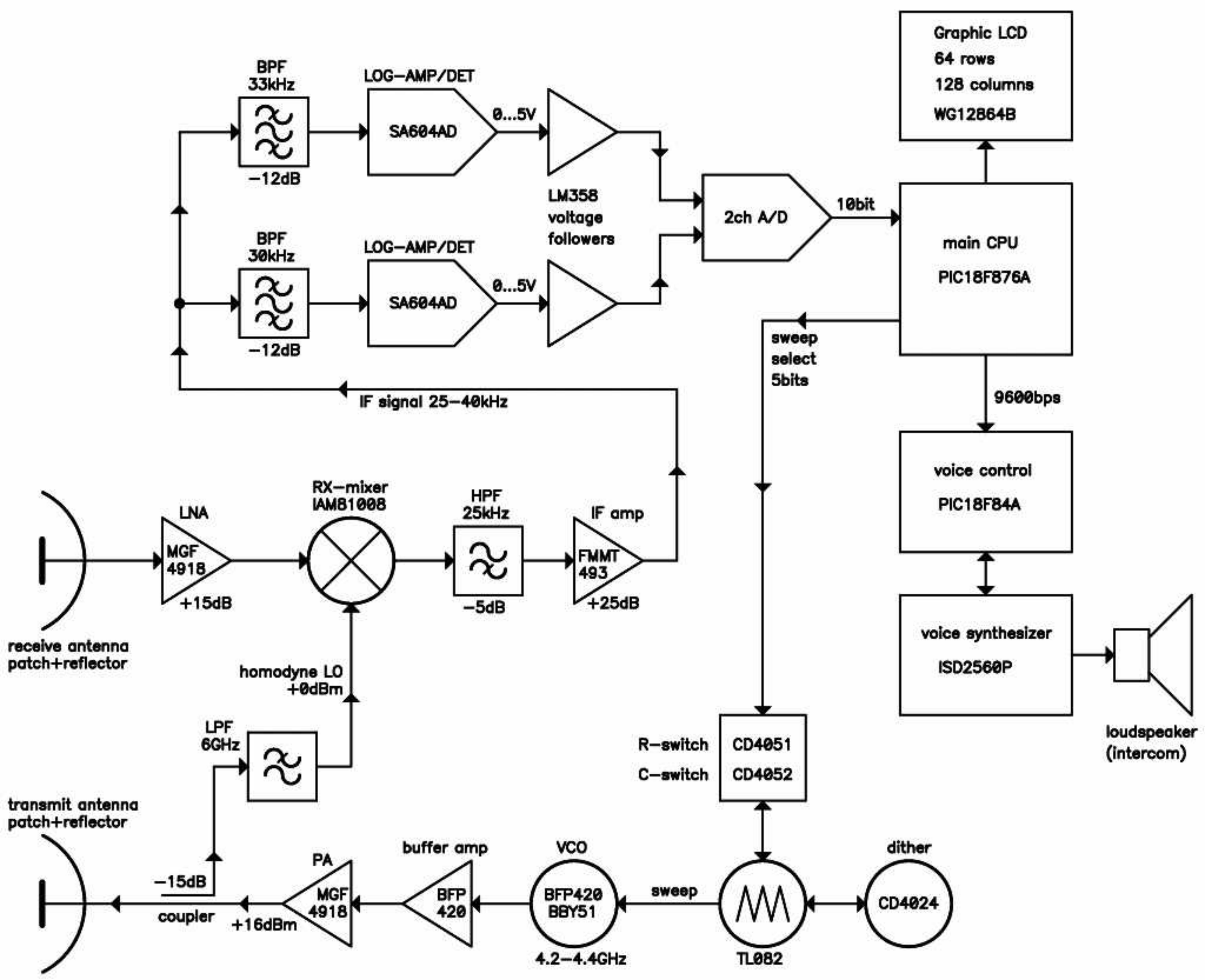
altitude	first Fresnel zone radius	antenna beam radius
10ft (3m)	1.1ft (0.32m)	7.5ft (2.25m)
100ft (30m)	3.4ft (1m)	75ft (22.5m)
1000ft (300m)	10.6ft (3.2m)	750ft (225m)

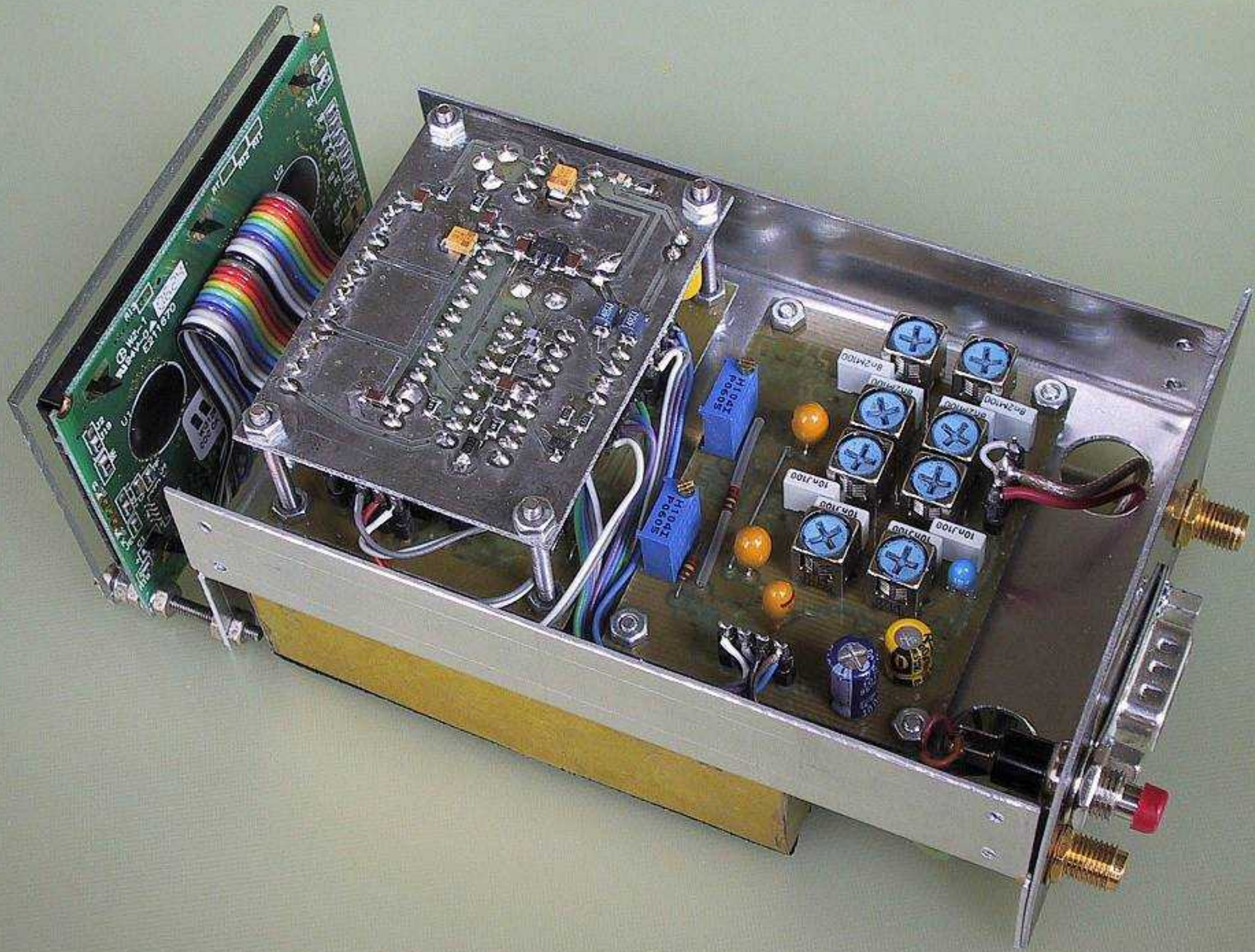
wavelength = 7cm = 0.07m	antenna directivity
@ 4.3GHz	D = 10 = 10dBi


SPECULAR REFLECTION from smooth target
main reflection
Reflection intensity (log scale)
altitude above ground
double–pass reflection
Reflection delay (linear time scale)


DIFFUSED REFLECTION from rough target
Reflection intensity (log scale)
altitude above ground
Reflection delay (linear time scale)

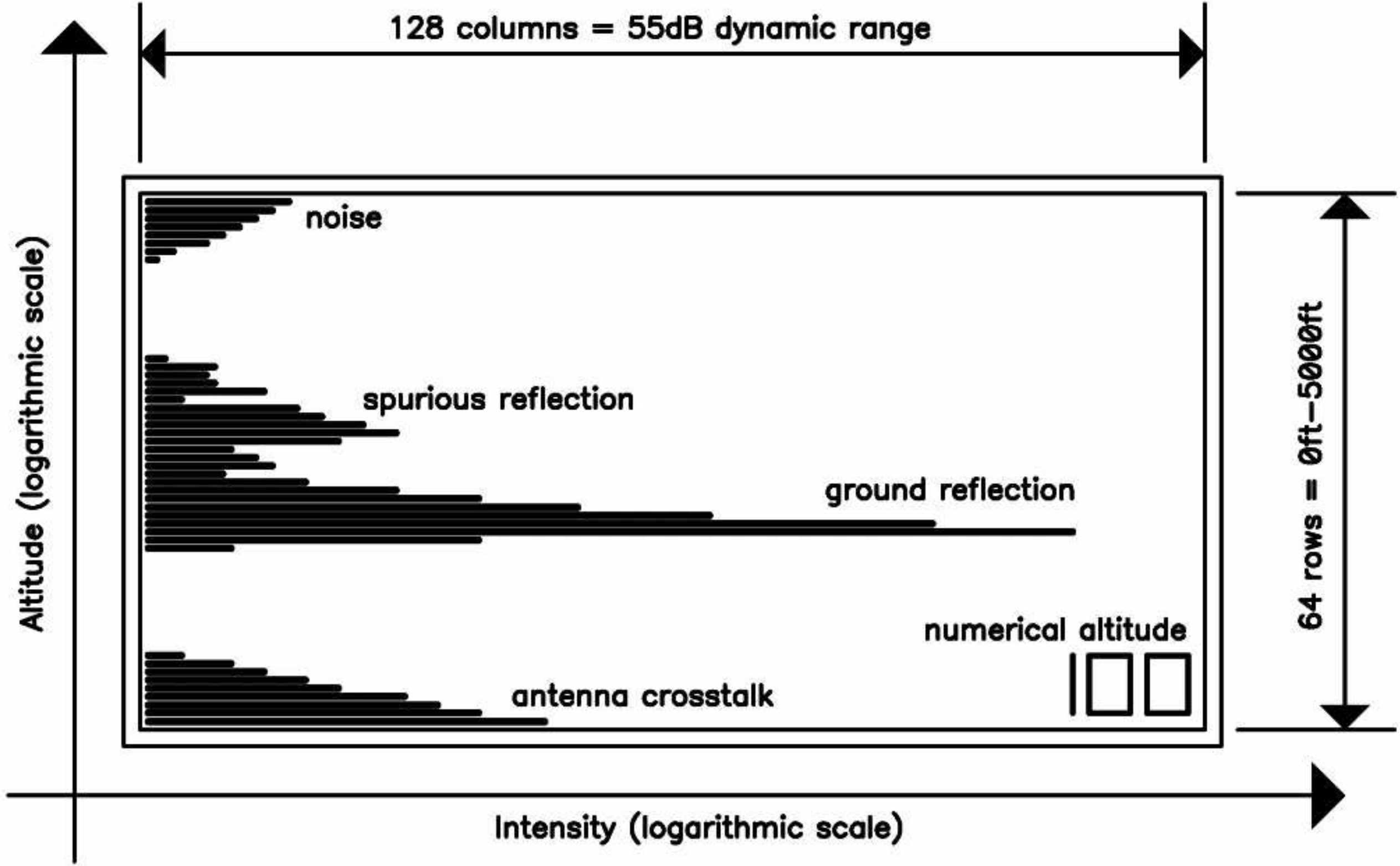

aircraft
TX
RX
incident wave
reflected wave (delayed)
radio altitude
runway
altitude = K x abs(Ftx – Frx)
frequency
FM–deviation
TX–frequency
RX–frequency (delayed!)
frequency difference
time delay
triangular sweep period
time

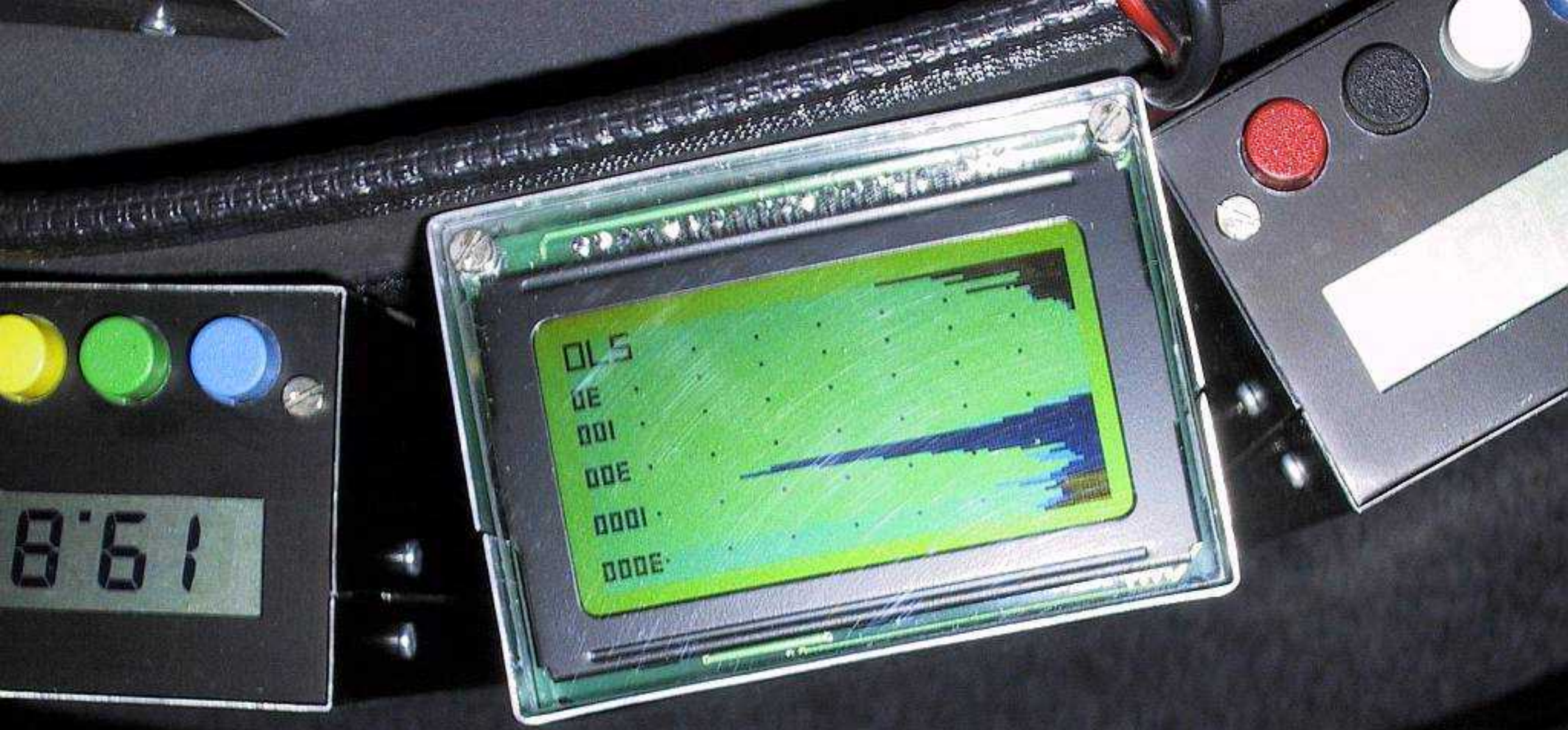

Graphic LCD
64 rows
128 columns
WG12864B
BPF
33kHz
LOG-AMP/DET
SA604AD
0...5V
-12dB
LM358
voltage
followers
BPF
30kHz
LOG-AMP/DET
SA604AD
0...5V
-12dB
2ch A/D
10bit
main CPU
PIC18F876A
sweep
select
5bits
IF signal 25-40kHz
9600bps
voice control
PIC18F84A
RX-mixer
IAM81008
HPF
25kHz
IF amp
LNA
MGF
4918
+15dB
FMMT
493
+25dB
-5dB
receive antenna
patch+reflector
voice synthesizer
ISD2560P
loudspeaker
(intercom)
homodyne LO
+0dBm
LPF
6GHz
R-switch
C-switch
CD4051
CD4052
transmit antenna
patch+reflector
-15dB
coupler
+16dBm
PA
MGF
4918
buffer amp
BFP
420
VCO
BFP420
BBY51
4.2-4.4GHz
sweep
dither
CD4024
TL082

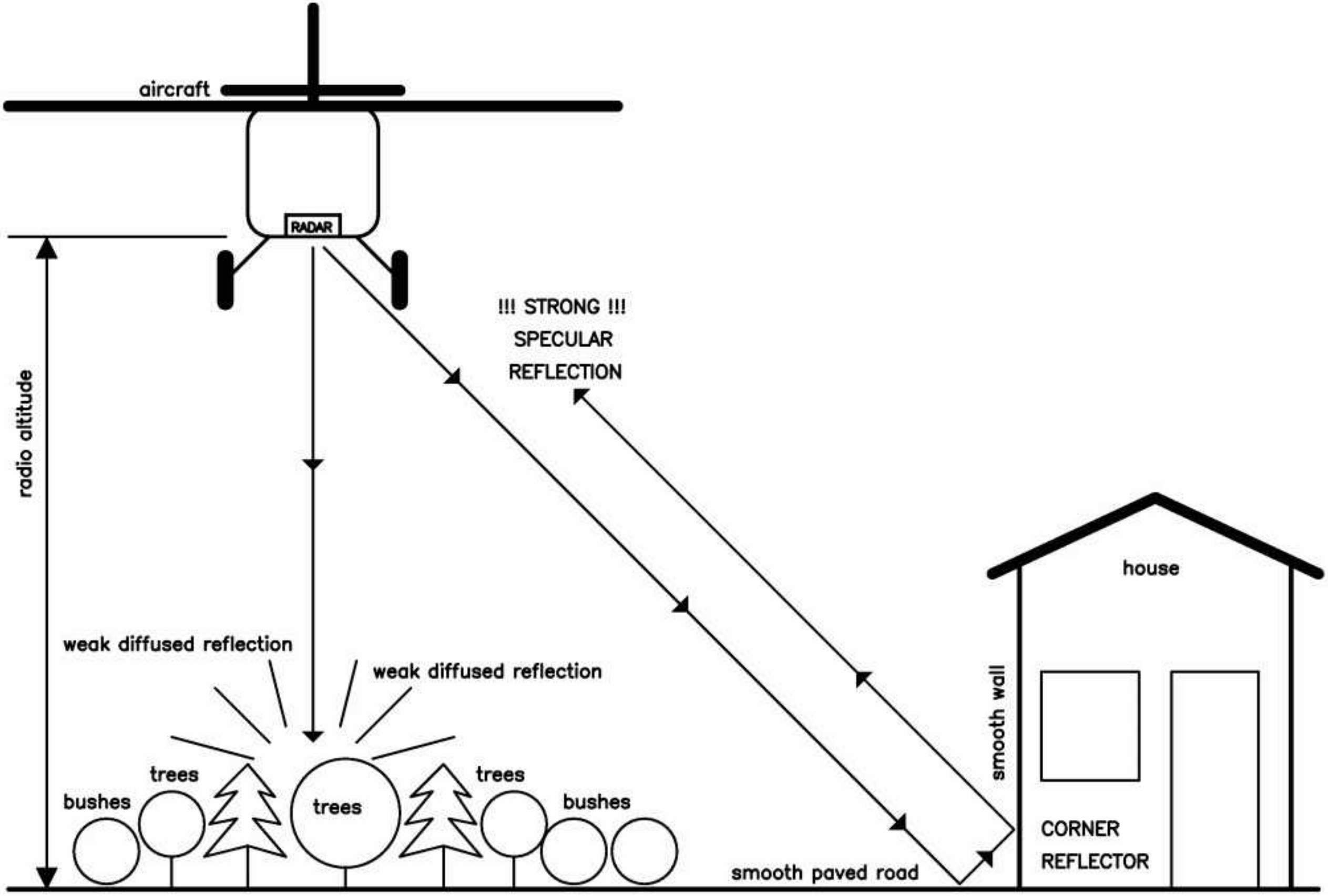



X 502
3608
1405 18CL
FJJ8825
SP9106
D4052BCN
IM5652BN
1n5M100
.15 J63
33nM100
M810
221
221
221
221

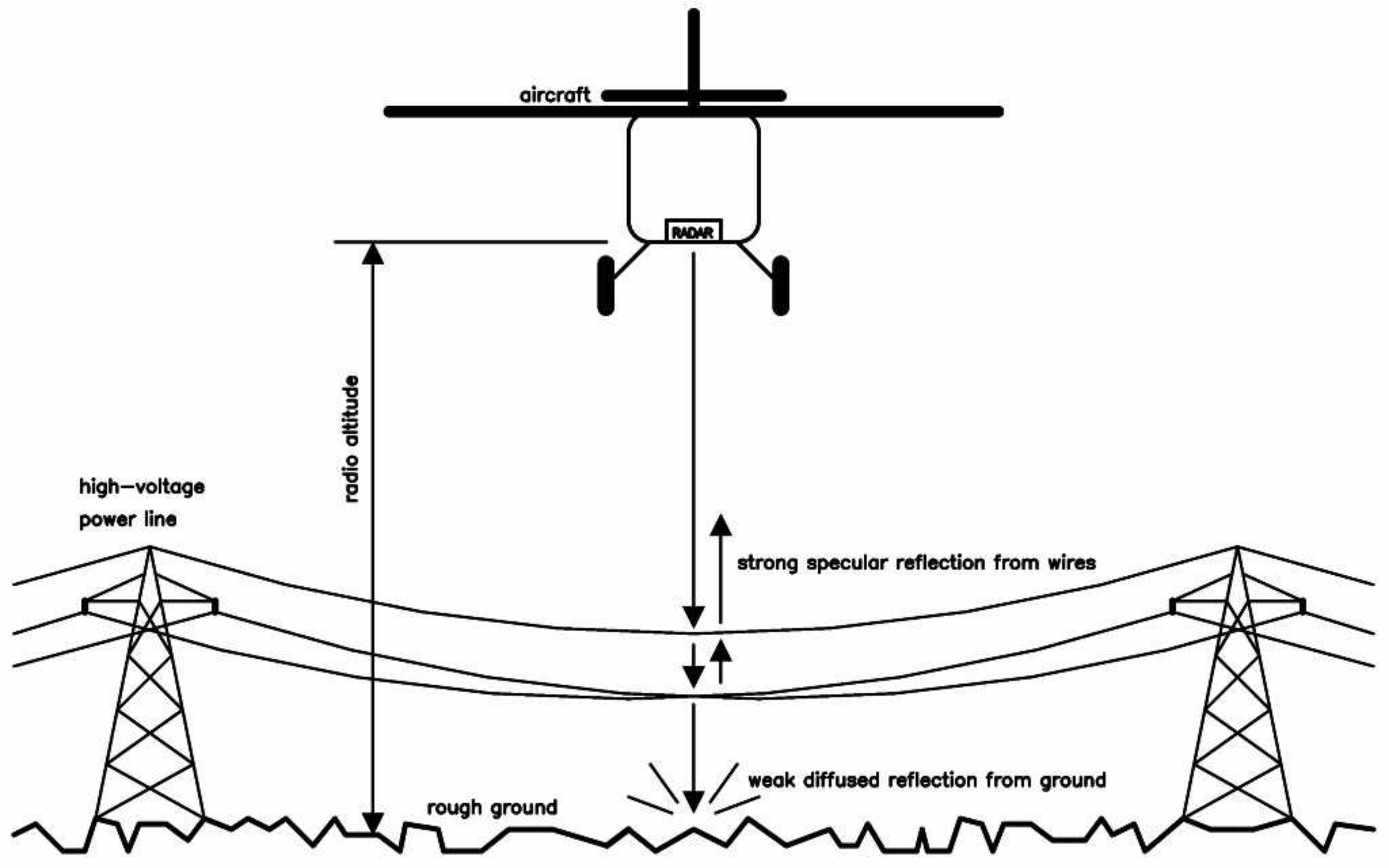

SP9106
4052BCN
MC6852BN
4051BCL
JUB625

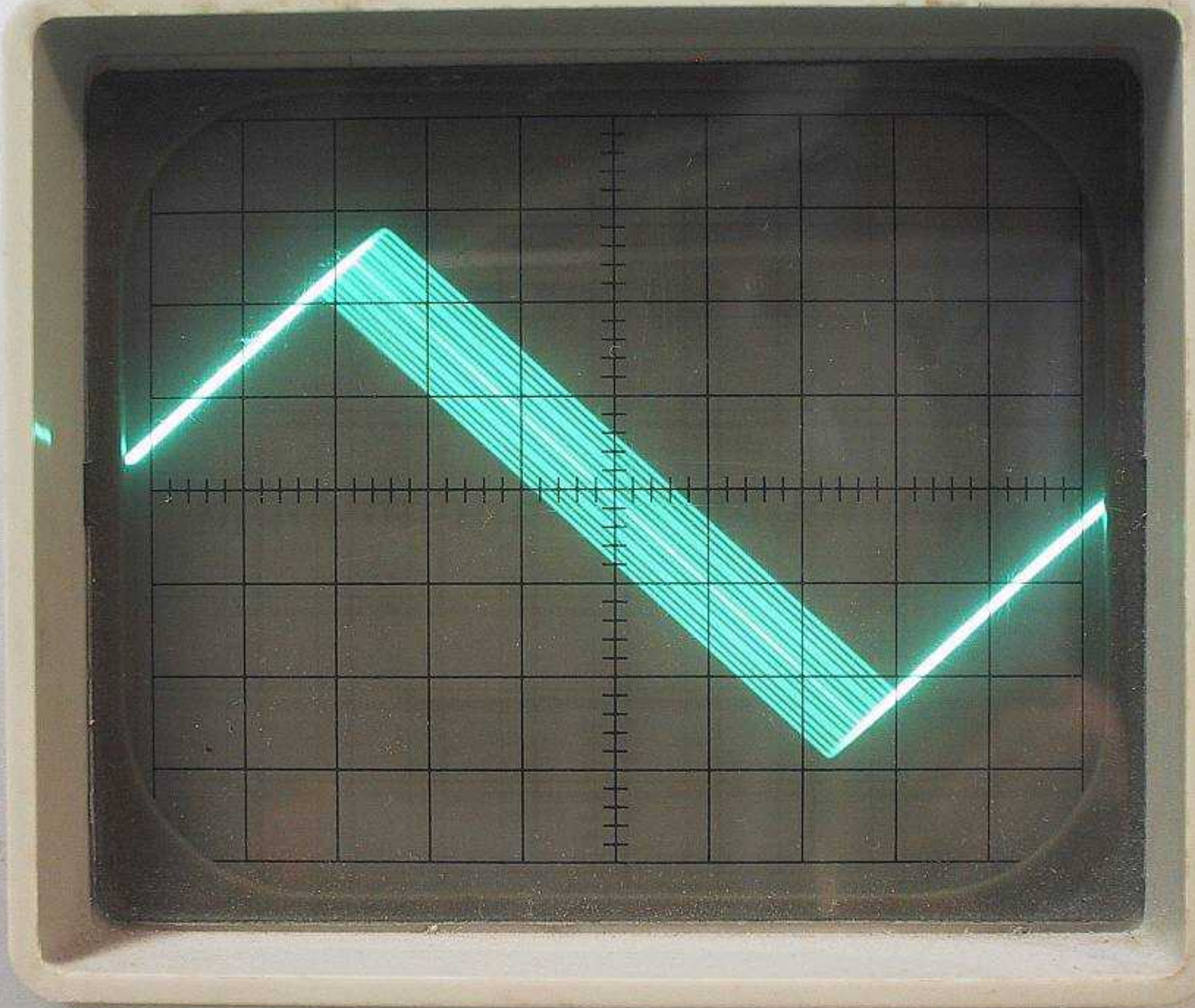

128 columns = 55dB dynamic range
Altitude (logarithmic scale)
noise
spurious reflection
ground reflection
numerical altitude
antenna crosstalk
64 rows = 0ft–5000ft
Intensity (logarithmic scale)


8'61
OLS
0E
001
00E
0001
000E

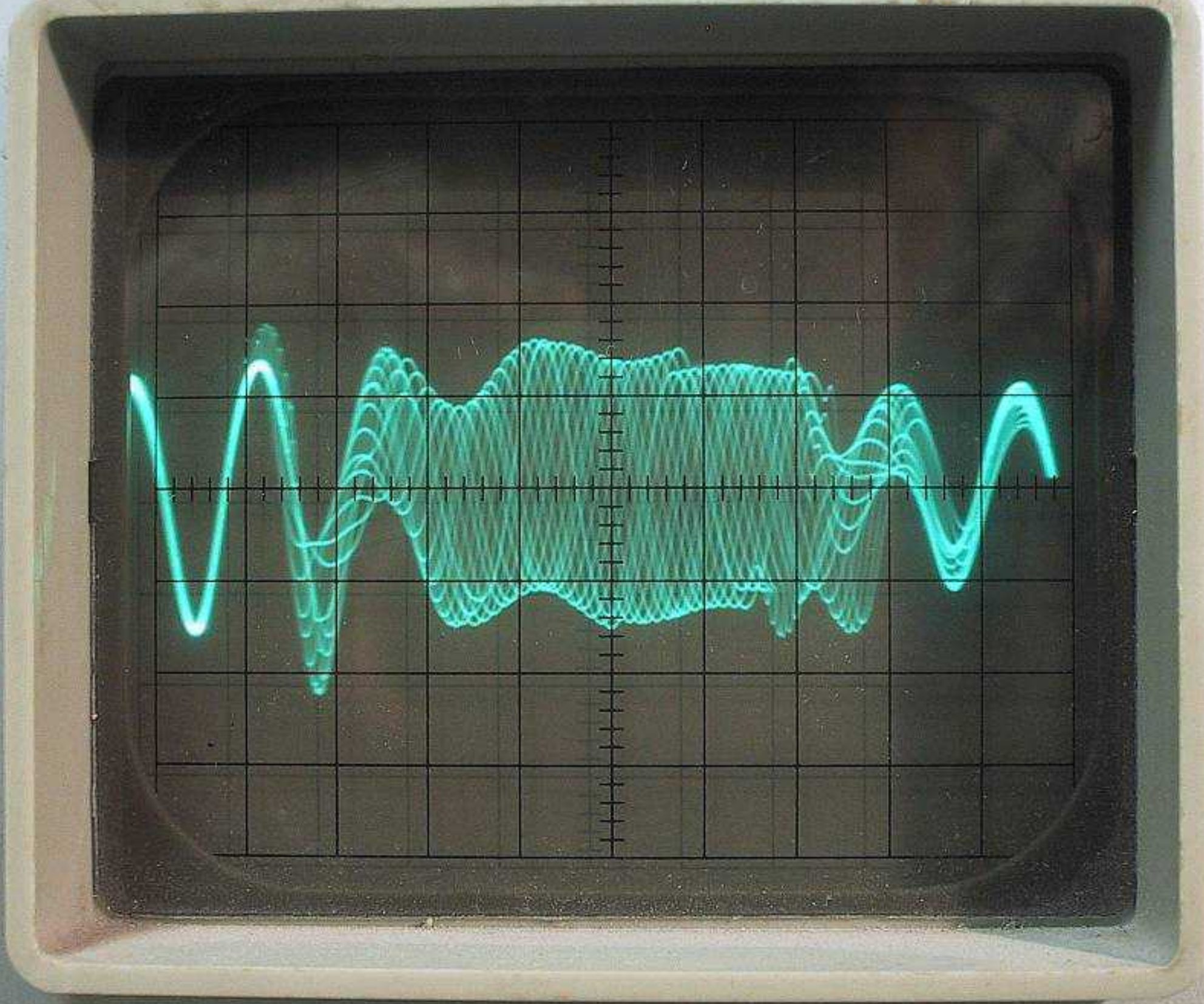

aircraft
RADAR
radio altitude
!!! STRONG !!!
SPECULAR
REFLECTION
weak diffused reflection
weak diffused reflection
trees
bushes
trees
trees
bushes
house
smooth wall
CORNER
REFLECTOR
smooth paved road


19.85


aircraft
RADAR
radio altitude
high–voltage
power line
strong specular reflection from wires
weak diffused reflection from ground
rough ground



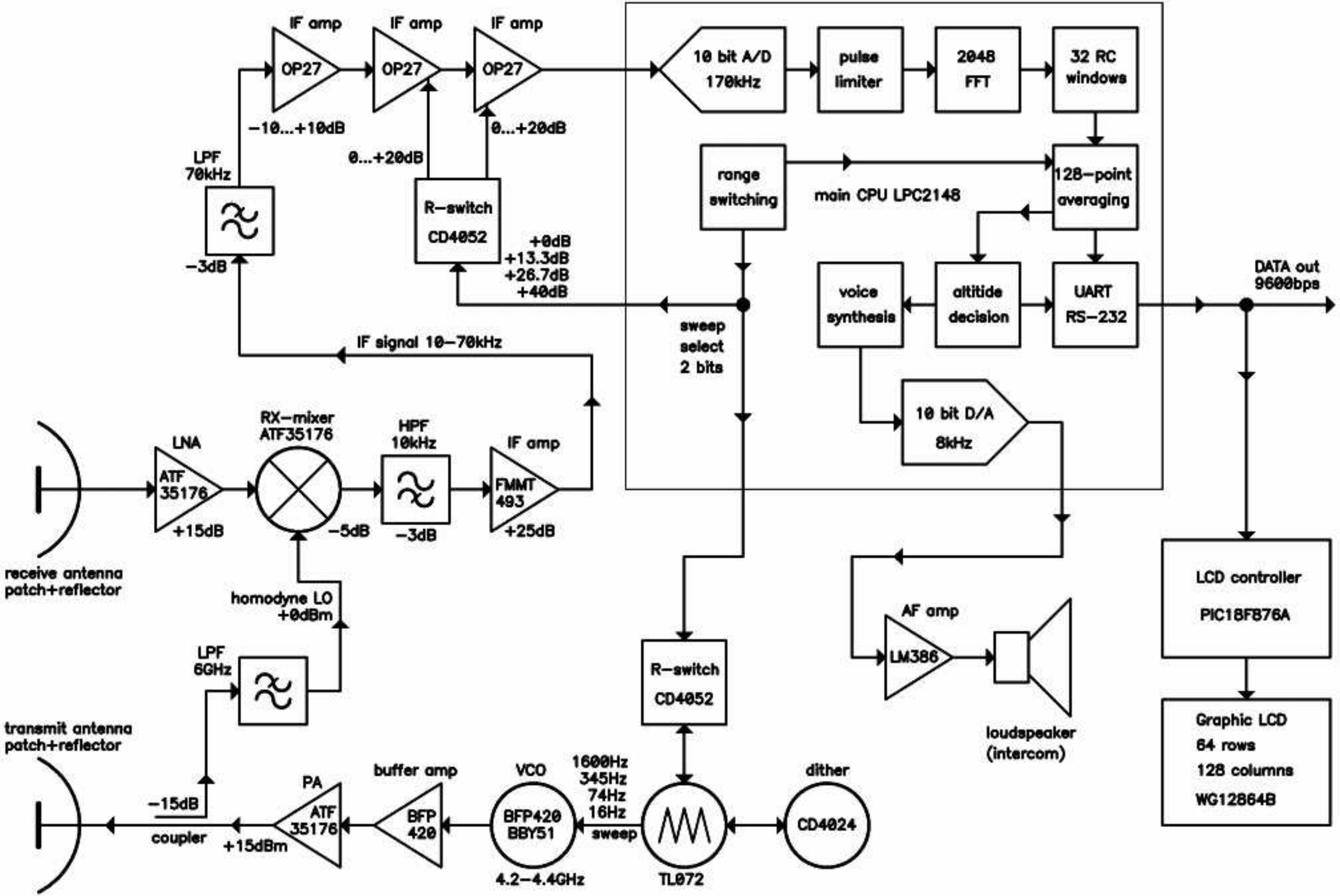
PHILIPS
MADE IN HOLLAND

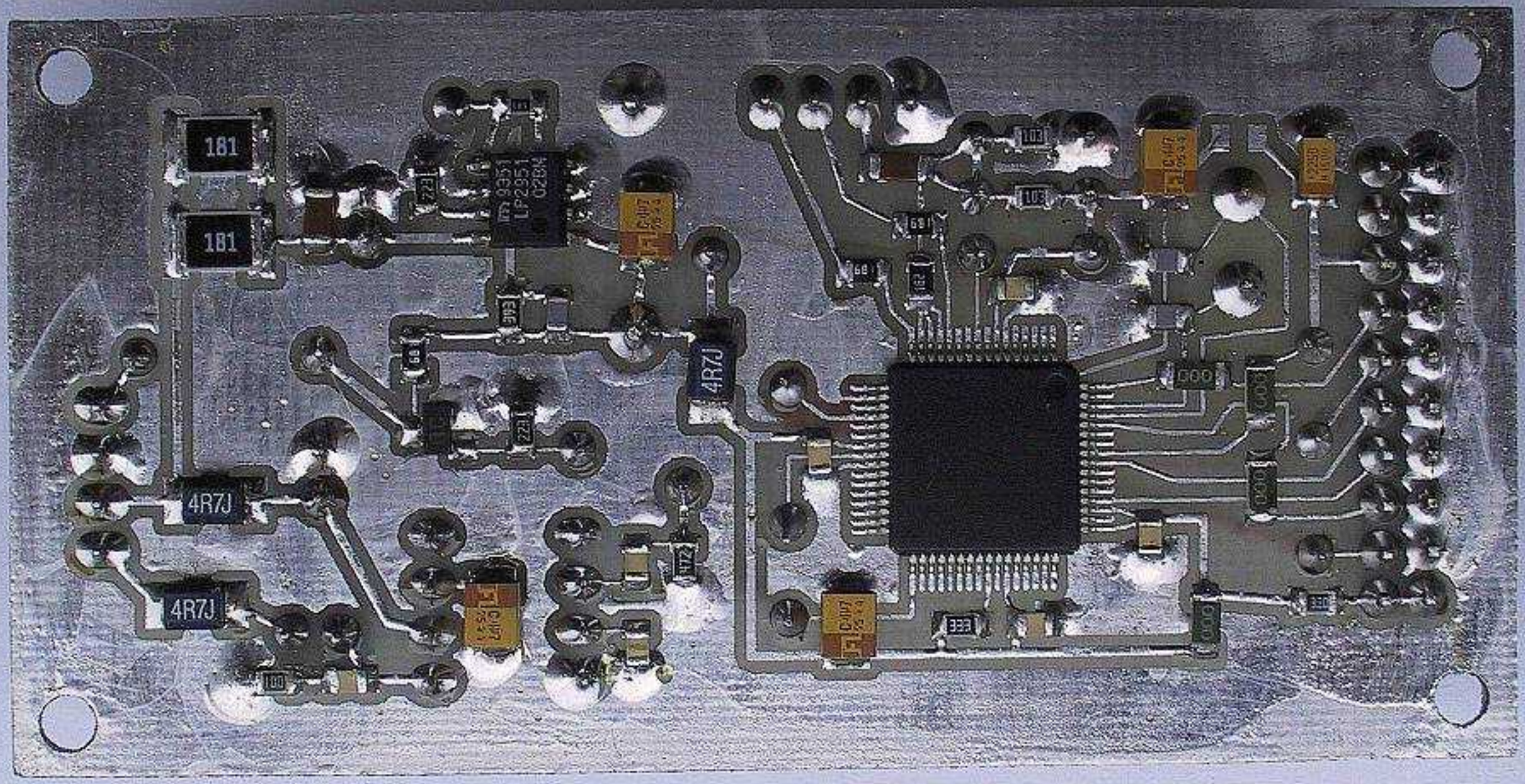


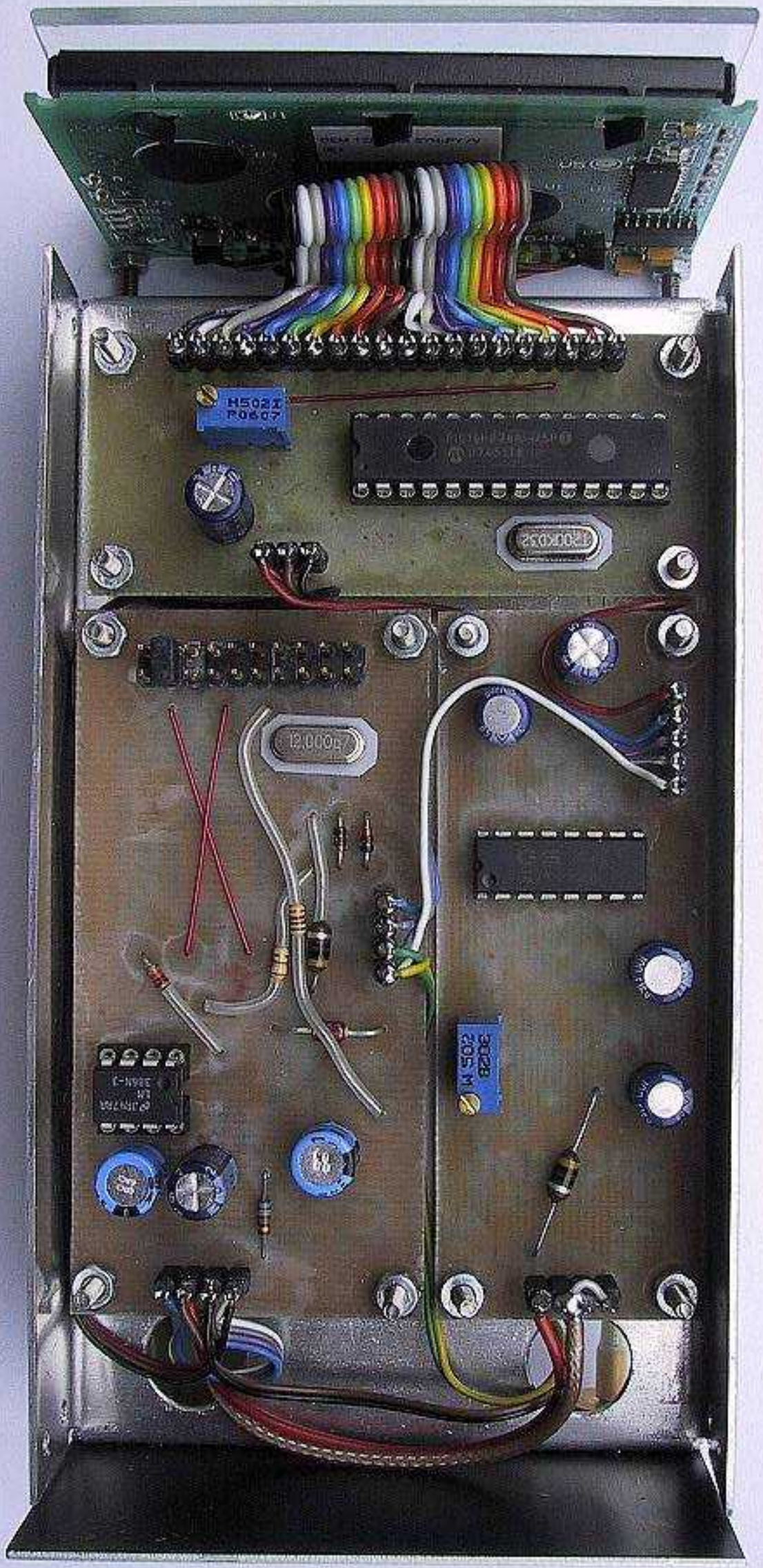
MEA

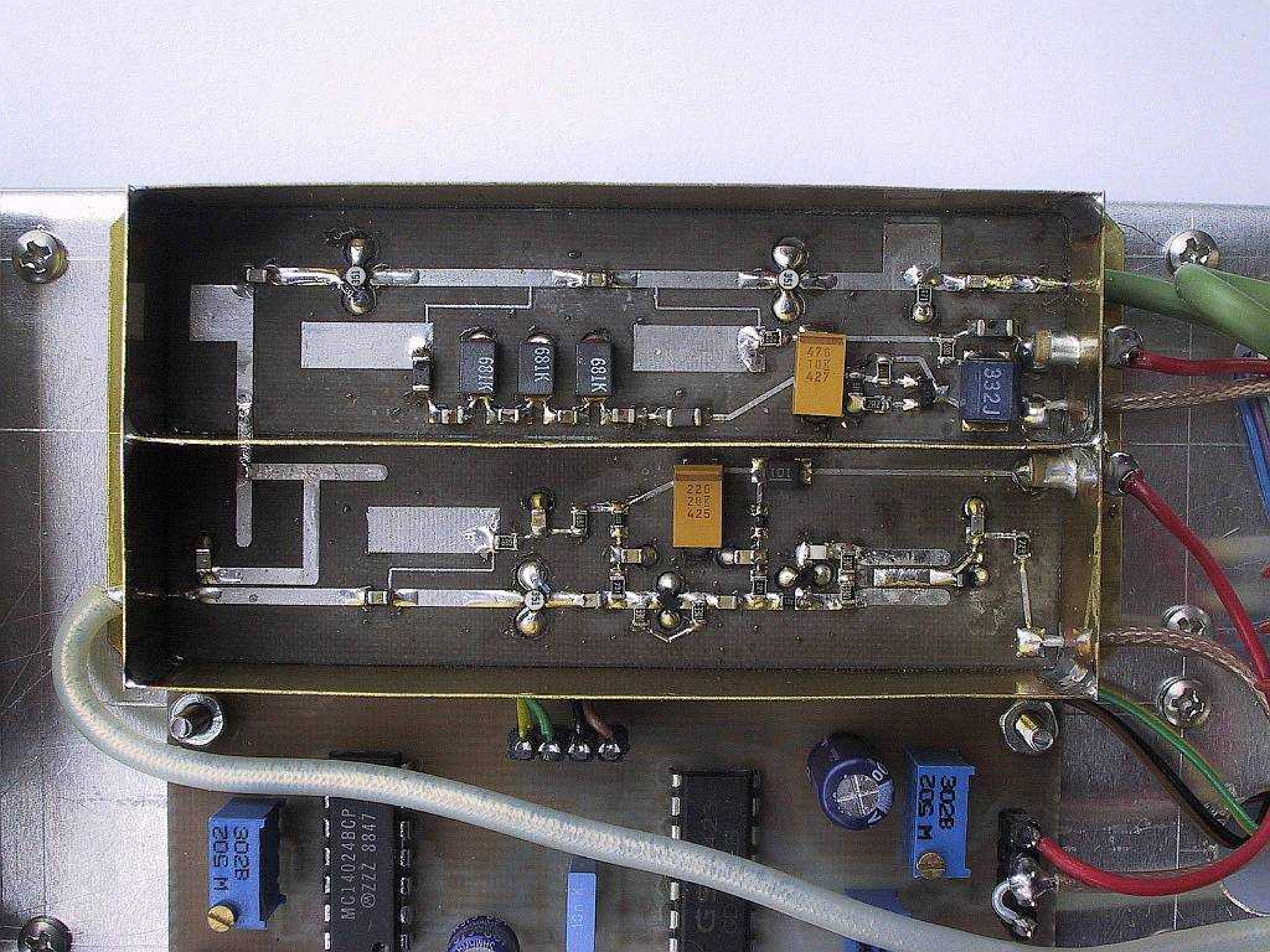
TO

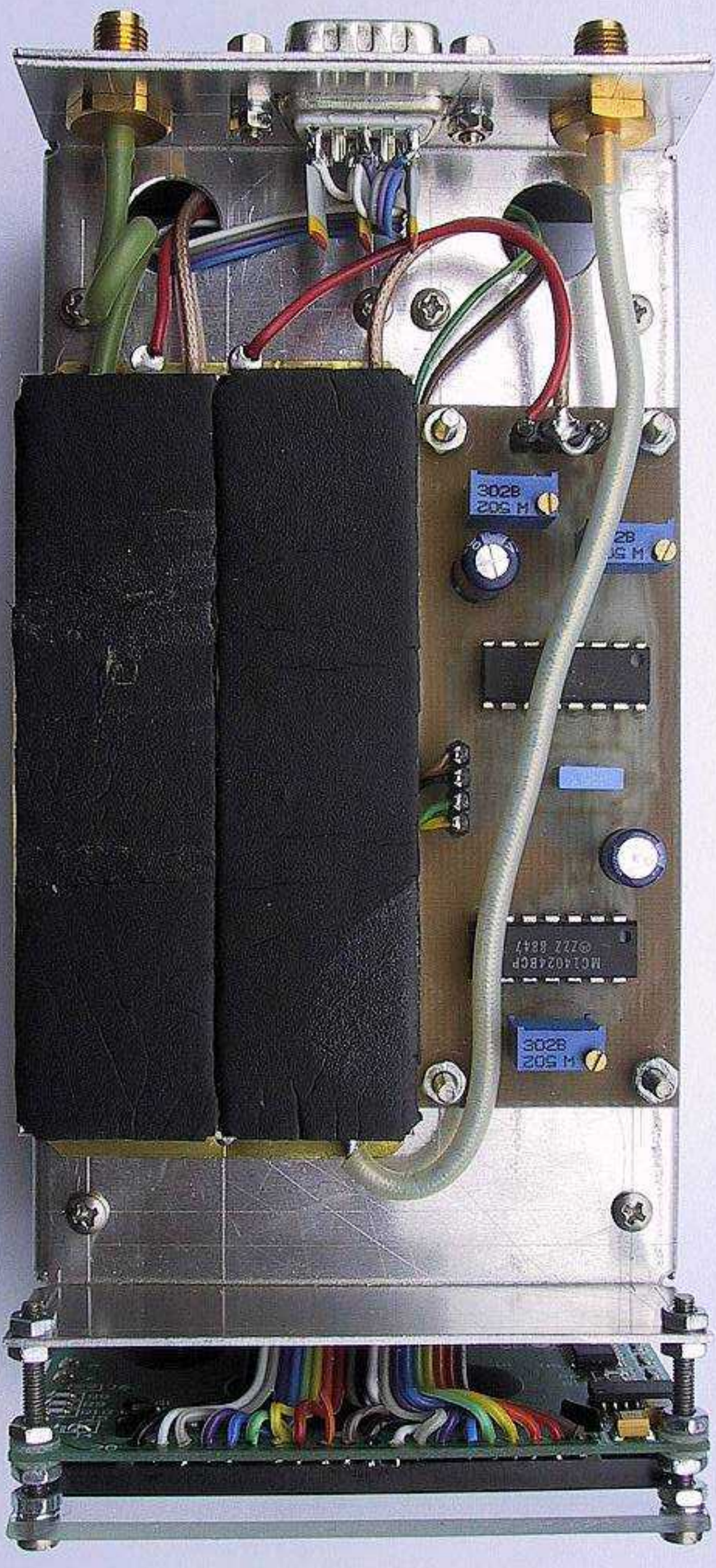
HF re

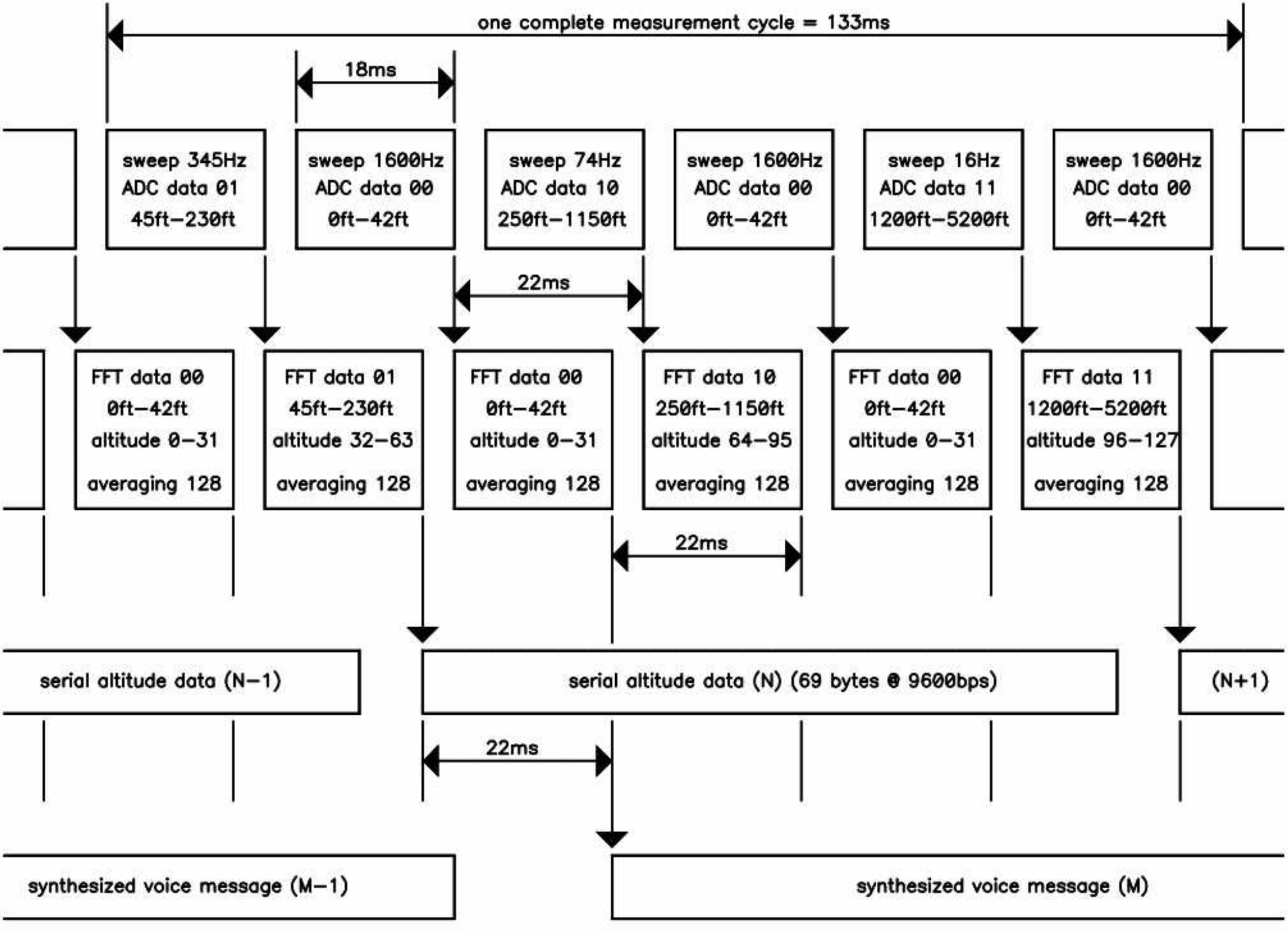

IF amp
IF amp
IF amp
OP27
OP27
OP27
−10...+10dB
0...+20dB
0...+20dB
LPF
70kHz
−3dB
R−switch
CD4052
+0dB
+13.3dB
+26.7dB
+40dB
10 bit A/D
170kHz
pulse
limiter
2048
FFT
32 RC
windows
range
switching
main CPU LPC2148
128−point
averaging
voice
synthesis
altitide
decision
UART
RS−232
DATA out
9600bps
sweep
select
2 bits
IF signal 10−70kHz
10 bit D/A
8kHz
RX−mixer
ATF35176
LNA
ATF
35176
+15dB
−5dB
HPF
10kHz
−3dB
IF amp
FMMT
493
+25dB
receive antenna
patch+reflector
homodyne LO
+0dBm
LCD controller
PIC18F876A
AF amp
LM386
loudspeaker
(intercom)
LPF
6GHz
R−switch
CD4052
Graphic LCD
64 rows
128 columns
WG12864B
transmit antenna
patch+reflector
−15dB
coupler
PA
ATF
35176
+15dBm
buffer amp
BFP
420
VCO
BFP420
BBY51
4.2−4.4GHz
1600Hz
345Hz
74Hz
16Hz
sweep
TL072
dither
CD4024

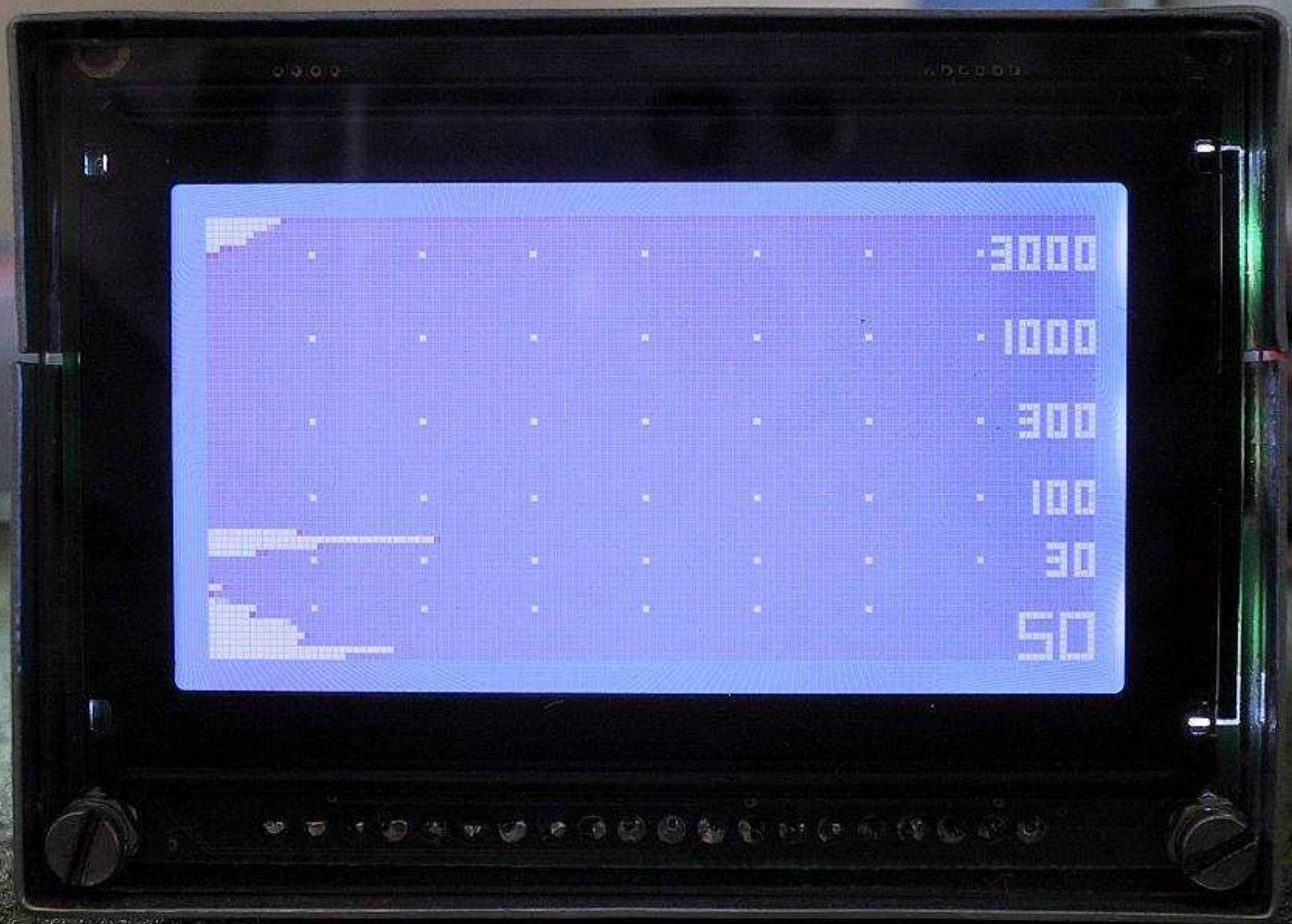

181
181
4R7J
4R7J
4R7J


H502K
P0607
12.000MZ


681K
681K
681K
332J
MC14024BCP


302B
302B


one complete measurement cycle = 133ms
18ms
sweep 345Hz
ADC data 01
45ft–230ft
sweep 1600Hz
ADC data 00
0ft–42ft
sweep 74Hz
ADC data 10
250ft–1150ft
sweep 1600Hz
ADC data 00
0ft–42ft
sweep 16Hz
ADC data 11
1200ft–5200ft
sweep 1600Hz
ADC data 00
0ft–42ft
22ms
FFT data 00
0ft–42ft
altitude 0–31
averaging 128
FFT data 01
45ft–230ft
altitude 32–63
averaging 128
FFT data 00
0ft–42ft
altitude 0–31
averaging 128
FFT data 10
250ft–1150ft
altitude 64–95
averaging 128
FFT data 00
0ft–42ft
altitude 0–31
averaging 128
FFT data 11
1200ft–5200ft
altitude 96–127
averaging 128
22ms
serial altitude data (N–1)
serial altitude data (N) (69 bytes @ 9600bps)
(N+1)
22ms
synthesized voice message (M–1)
synthesized voice message (M)


3000
1000
300
100
30
50


19.85


19.17
S5-PCV
BRUNIGER
ALPHA


19.85
BRAUNIGER
S5-PCX

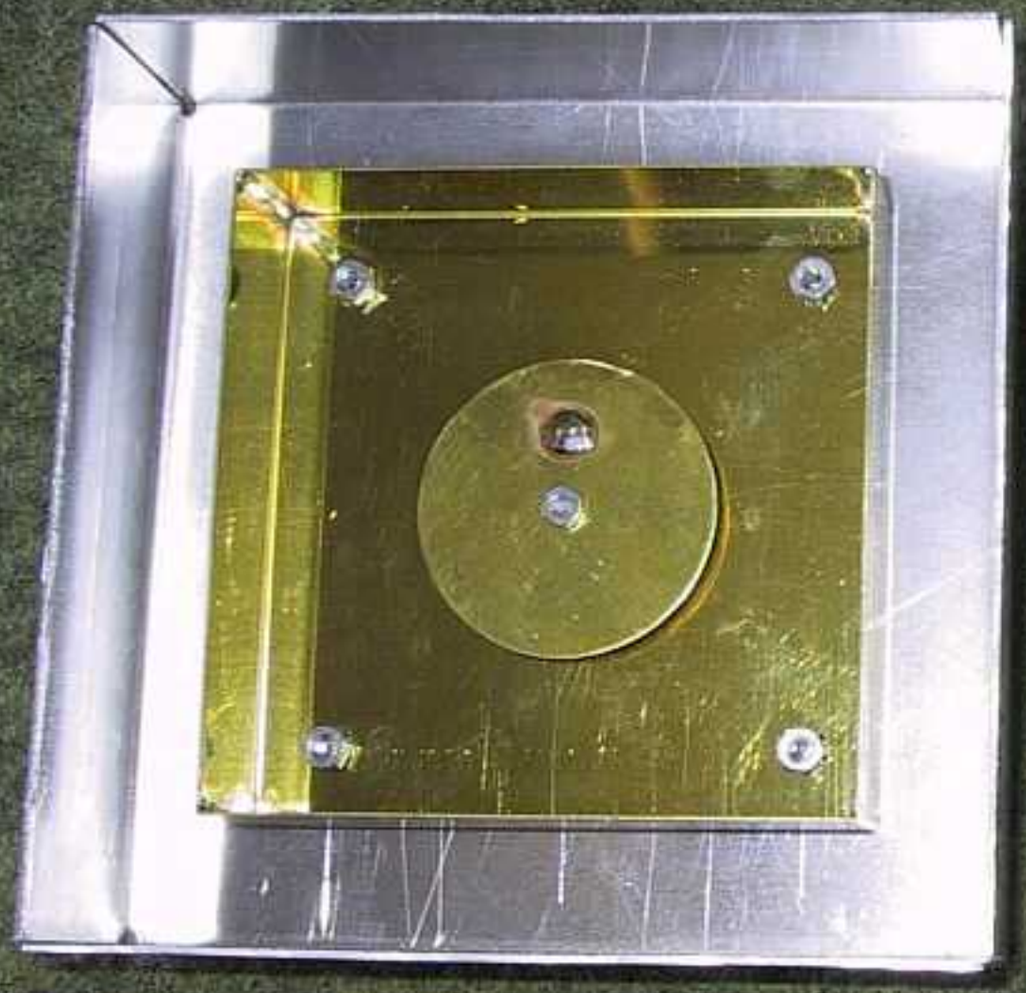

19.85
SS-POV


ADRIA
ADRIA AIRWAYS

Operated by

CityLine

D-ACLL



233	VLO	(EXT) (L/G EXTENSION)	250
193	VLO	(RET) (L/G RETRACTION)	200
	VLE	(L/G EXTENDED)	250

A/C 7024
D-ACLL
SELCAL CLDR

TAS 0 GS 0 SAT 22C TAT 22C

0NM 00:00
---NM -:-- --:--
---NM -:-- --:--
---NM -:-- --:-- ----- KG

TCAS OFF
ABV/BLW
ALT 014

MAG

MAP

TERRAIN DISPLAY FAIL
FMS NAV INVALID

4600

YD

60
40

FD

ATT

VT 90
V2 90
VR 90
V1 90
126

600
500
400
300
200

0 FT 1014HPA

MAG

LOC2
CRS 305
0.9 NM
LJB

TCAS 1 2 4
OFF
0.0

ADF1
ADF2

R-ALT ANTENNA BLOCKER
PN: FEMV0001

NAS 1089
American Badge
REM

Subject: Spaceship 2 radio altimeter
Date: Tue, 7 Nov 2006 14:13:41 -0800
From: "Shawn Keller" <shawn.keller@scaled.com>
To: <s53mv@uni-mb.si>

Dear Mr. Vidmar,

I ran across your website, and was very impressed with your technical expertise. Very impressive set of instrumentation. I particularly like the fact that you prefer PIC microcontrollers, as that is my favorite type to implement in my own designs.

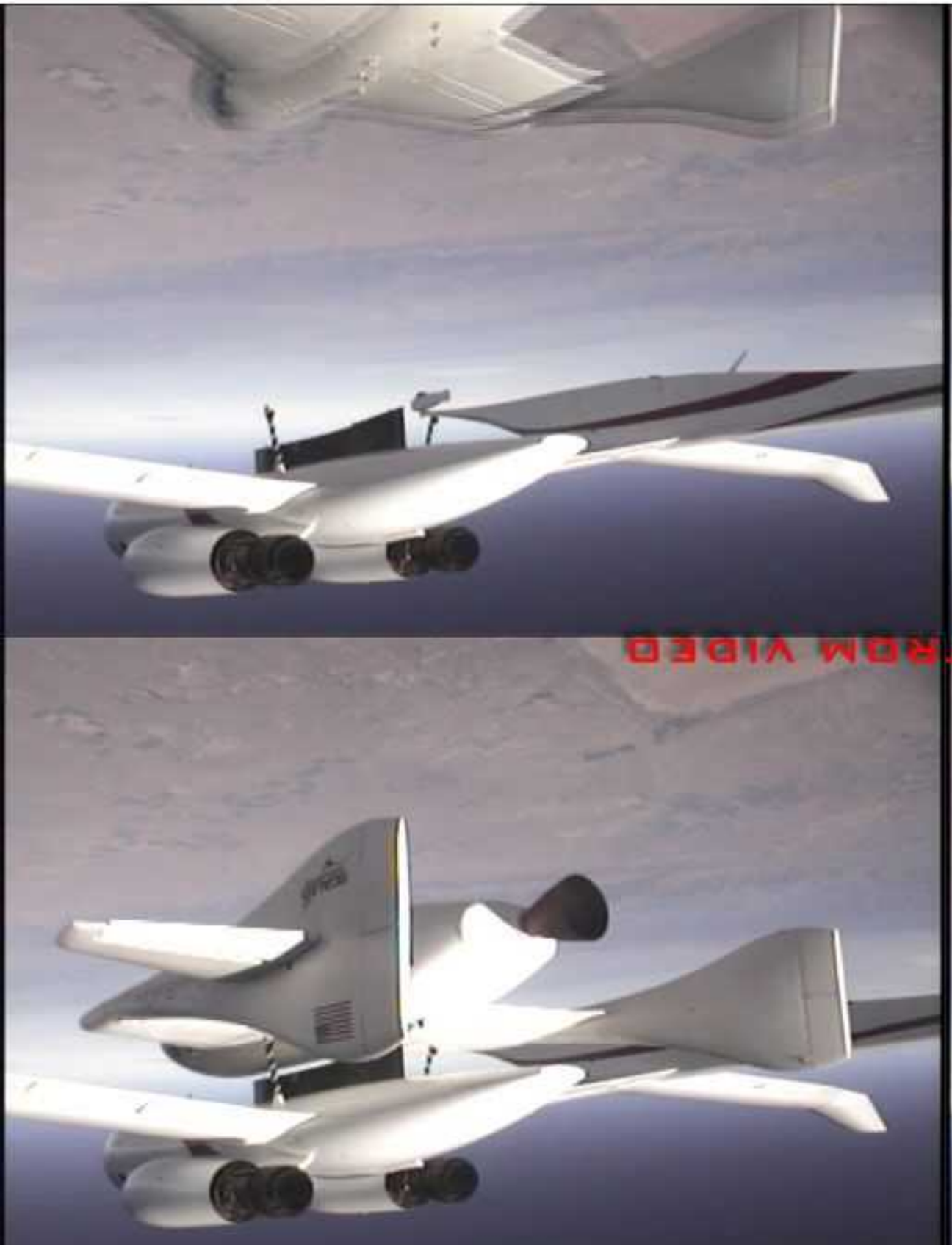
I don't know if you are familiar with SpaceShipOne, the first manned commercial spacecraft that my company built and flew in 2004. See www.scaled.com. It made three sub-orbital trips to space to win the X-prize and afterwards was retired the the National Air and Space museum in Washington, DC, USA. I am the electronics engineer for Scaled and have designed most of the electrical systems for Scaled for the past 12 years.

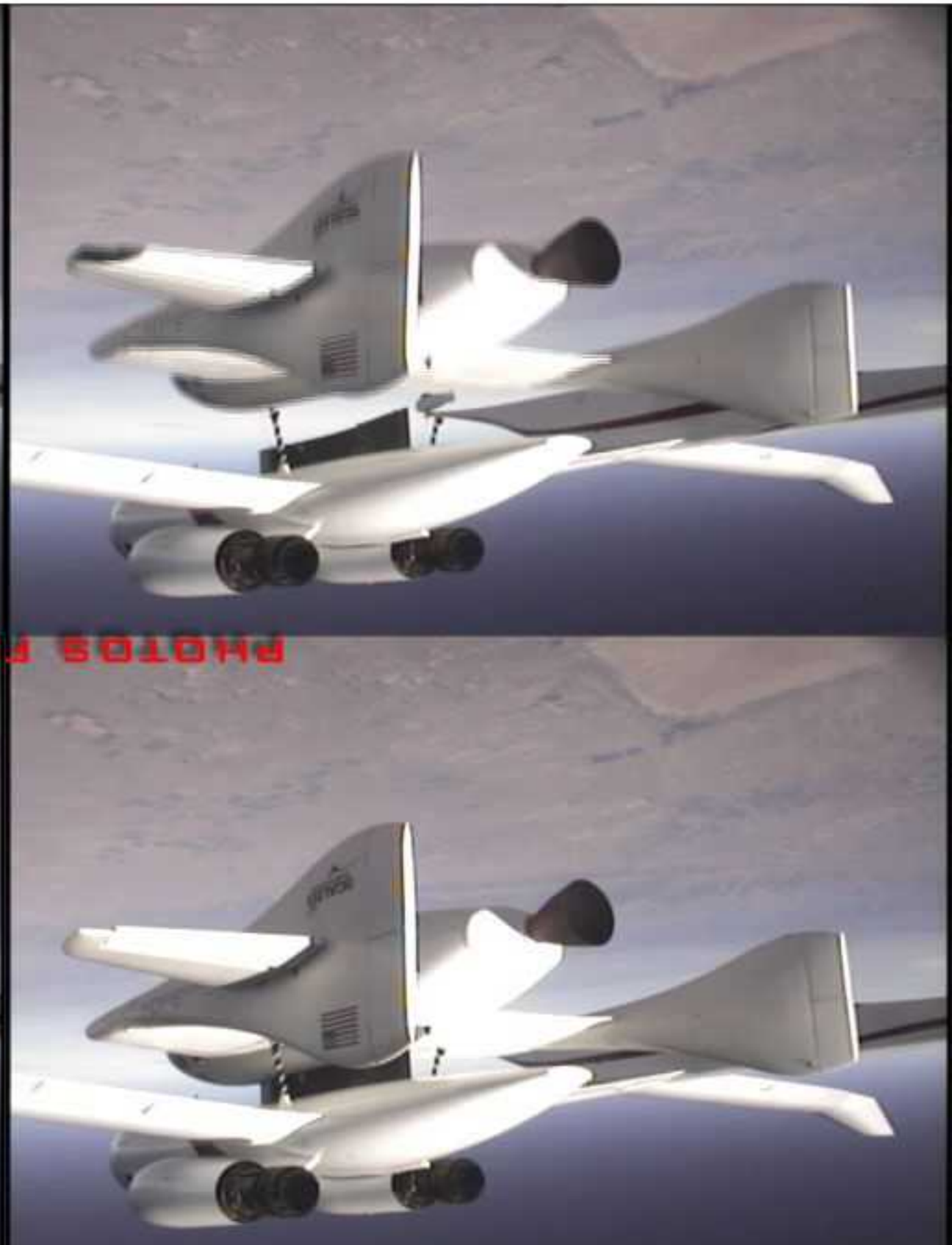
We are now in development of SpaceShipTwo (SS2), the commercial follow on to SS1, and we are calling out a radio altimeter to be installed to assist with the landings. I was wondering how you would feel about duplicating your radio altimeter design for us, particularly the RF sections, with a few small modifications. The first SS2 will strictly be a prototype and remain in the experimental category. It is likely we would use a commercial unit for the follow on vehicles.

What do you think, interested?

Sincerely,

Shawn Keller
Electronics Engineer
Scaled Composites, LLC.
1624 Flight Line
Mojave, CA 93501
(661) 824-6328





PHOTOS FROM VIDEO

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N328KF
PHOTOS FROM VIDEO
N328KF


N328KF
N328KF

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LIPQ
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LFKO
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Otok Cres
Otok Rab
Otok Losinj
Otok Pag
Dugi Otok


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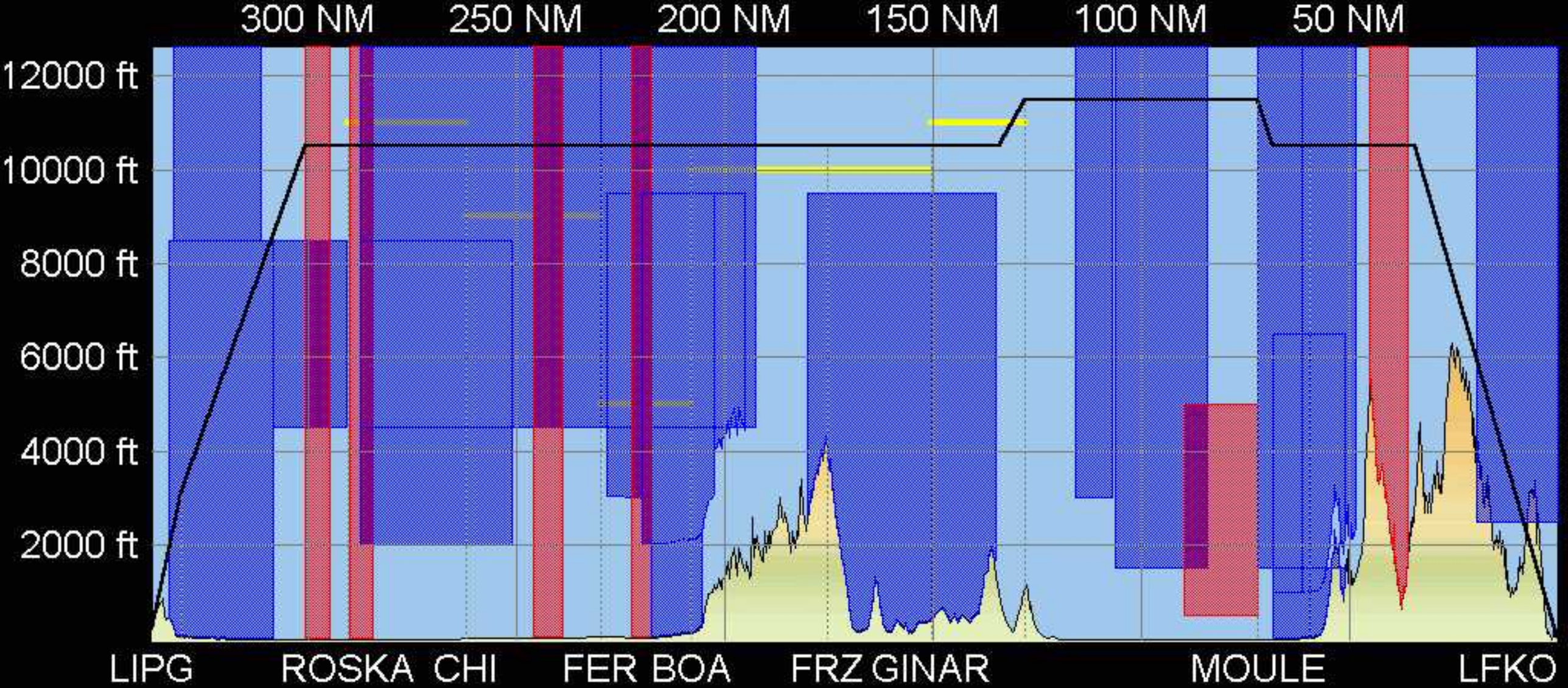
Corsica
Italy


300 NM
250 NM
200 NM
150 NM
100 NM
50 NM
12000 ft
10000 ft
8000 ft
6000 ft
4000 ft
2000 ft
LIPG
ROSKA
CHI
FER
BOA
FRZ
GINAR
MOULE
LFKO


F-GMMN