N73-32115

SOLID STATE S-BAND POWER AMPLIFIER

FINAL REPORT

for the

NASA

Marshall Space Flight Center

Huntsville, Alabama

CONTRACT NAS-8-28763

ADVANCED DEVELOPMENT

ITT

DEFENSE COMMUNICATIONS

492 River Road, Nutley, New Jersey 07110

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A Subsidiary of the International Telephone and Telegraph Corporation

492 River Road, Nutley, New Jersey, 07110

TABLE OF CONTENTS

1. INTRODUCTION

The following is a report on the final design approach and specifications for the solid state S-band power amplifier in accord with the specifications of contract NAS-8-28763. Modifications from the design proposed in ITT Defense Communications proposal 34024 have been incorporated to improve efficiency and meet input overdrive and noise floor requirements.

2. SYSTEM DESIGN

2.1 SYSTEM BLOCK DIAGRAM

The driver and power amplifier block diagrams are shown in Drawings 1261662 and 663. A number of key features of this design should be noted. To safely apply up to one watt of power to the input 6 db of attenuation has been incorporated. Since the 12 db isolation resulting from this attenuator provides adequate input standing wave ratio, the input circulator has been eliminated. An additional stage of gain has been incorporated in the driver amplifier to compensate for the loss. There is no impact on the system noise floor, because measurements on the MSC 80064 have shown a noise figure of 7.9 db per stage, which gives a driver amplifier noise figure for two stages of 8.45 db from the formula

$$NF = F_1 + \frac{F_2 - 1}{G}$$

where NF = noise figure for the total system

F_1, F_2 = noise figure of the first and second stages

G = gain of the first stage

The total system noise floor, with an amplifier gain of 39.4 db is

$$\text{Noise Floor} = kTB\,\frac{\text{dbm}}{\text{hz}} + NF + G_{amp} + \text{Bandwidth factor}$$

$$NF_{tot} = -174 + 8.45 + 39.4 + 70$$

$$= \frac{-56.15 \text{ dbm}}{10 \text{ mhz}}$$

To meet the out of band noise floor specification of -95 dbm/10 mhz at 2104 mhz, an additional 38.85 db of rejection must be supplied by the output filter. This is within the limits of the filter specification.

The total amplifier efficiency has been improved to 36% by newer transistors.

2.2 SYSTEM SPECIFICATIONS

The system specifications are summarized below.

Title	NASA Spec. Requirements	ITT Performance
Design		
Power consumption	95 watts max.	73 watts
Primary voltage	28 ± 4 vdc	28 ± 4 vdc
Performance		
Electrical		
Drive power	25 to 50 mw, no damage should occur by input power levels from 0.0 to 1.0 watts, cw	25 to 50 mw drive to obtain 20 watt, min. output 1 watt input drive capability
Output power	20 watts min. at optimum efficiency	23.5 watts @ efficiency
Life	Mtbf = 10,000 hrs	29,200 hour Mtbf
Terminal impedances	Input swr 1.3:1 max Output swr 1.5:1 max with all d-c removed from power amplifier	Input swr 1.25:1 Output swr 1.5:1 with or without d-c applied
Phase stability	add no more than 0.05 radian rms phase jitter to r-f input signal	0.05 radians rms phase jitter to input signal
Center frequency	2,250.5 mhz	2,250.5 mhz
Passband requirements	100 mhz, ± 1 db centered at 2,250.5 mhz	100 mhz, ± 1 db bandwidth center on 2,250.5 mhz

Title	NASA Spec. Requirements	ITT Performance
Environmental		
Temperature	meet all performance requirements when heat sink is maintained at -20 to -70 C. Thermal shock three cycles -20, +85 C.	-20 to +70 C output power and all operational characteristics
Vibration		
Random noise (5 min/plane)	20-59hz 0.04 g^2/hz 59-126 hz -9 db/octave 126-700 hz 0.40 g^2/hz 700-900 hz - 18 db/octave 900-2Khz 0.09 g^2/hz	designed to vibration specs
Sinusoidal sweep (1 octave/min.)	5-48 hz 0.125 inch 48-165 hz 15 g peak 165-2000 hz 10 g peak	designed to shock sweep specs
Shock	eight shocks per plane, 3 planes, 50 g for 11 msec.	designed to shock specs
Acceleration	1 min of 100 g in each of three planes	designed to acceleration specs
Vacuum and pressurization	within 24 hr. period leak rate shall be less than 1.0 psi when pressurized to 15 psig in a vacuum of 1.5×10^{-6} mmhz	designed to vacuum and pressurization specs
Humidity	MIL-STD-810, Method 507.1 Procedure 1	Designed to Humidity specs
R-F interference	per MIL-I-6181	per MIL-I-6181
Acoustical noise	per MIL-STD-810	per MIL-STD-810
Output load isolator	20 db isolation over passband	20 db, minimum 25 db, typical over passband

Title	NASA Spec. Requirements	ITT Performance
In-band spurious responses	60 db below output carrier measured within a 4 mhz bandwidth at output frequency 2,250.5 mhz	60 db below rated output at 2250.5 mhz
Output noise level	Internal noise gen. 2104 ± 5 mhz, less than -95 dbm	-95 dbm, minimum -100 dbm, typical
Output filter	Bandpass filter to reduce output noise spectrum of power amplifier	Output noise floor -95 dbm/10 mhz, Harmonics -60 db

2.3 SYSTEM MECHANICAL LAYOUT

The system mechanical layout is shown in the sketch, Drawing 1261673-B. The input circulator has been replaced by a fixed attenuator and an additional preamplifier stage has been incorporated.

Sketches and drawings used in the construction of this amplifier are bound together at the end of this document.

3. DRIVER AMPLIFIER SECTION

The driver section consists of the following components:

- input attenuator
- 3 stage amplifier
- matching networks

The specified input standing wave ratio of 1.3:1 has been satisfied as summarized in the following table.

Preamplifier input standing wave ratio	2.0:1 max.
Input standing wave ratio of fixed attenuator, variable attenuator and preamplifier.	1.28:1 max.
Specification requirements	1.3:1 max.

For 1 watt or +30 dbm applied to the input, the preamplifier receives 126 mw or +21 dbm, which is within acceptable limits.

3.1 INPUT ATTENUATOR

The fixed input attenuator satisfies the following specifications:

Specification	
Attenuation	dB
Input standing wave ratio	1.15:1
Power rating	1 watt at 75 C
Impedance	50
Frequency range	2.250 ghz ± 50 mhz
Size	5/16" diam., 1.5" long
Connectors	SMA

3.2 LOW LEVEL DRIVER AMPLIFIER STAGES

A circuit diagram of the three stage amplifier is shown in Drawing 1261662. The nominal output power is 3.5 watts with 3 mw input giving a gain of 30.7 db.

The overall specifications required for this amplifier chain are:

Frequency range	2.2-2.3 ghz
Gain	30 db
Gain flatness	1.5 db over band
Max. power output	5 watts (saturated)
Input standing wave ratio	2:1
Impedance	50 (nominal)
Maximum permissible	
Load mismatch	1.5:1 standing wave ratio
Maximum power in.	150 mw.
Efficiency	33%
Power requirements:	23-28 vdc and (last stage)
	22 vdc zener regulated

The driver amplifier was optimized and tested for -20 to +72 C. Minimum power output was 3.6 watts sufficient to drive the power amplifier. The power output variation was less than ± 0.5 db and the power consumption less than 14 watts.

The driver amplifier was driven with 1 watt of CW from 2.2 to 2.3 ghz with no apparent deterioration in performance. The second amplification stage is designed to saturate and cut off drive to the power stages to prevent catastrophic failure. From 25 watts to 50 watts drive the amplifier performed satisfactorily.

The input standing wave ratio with d-c power applied was less than 1.25:1. With d-c disconnected it was less than 1.5:1 over the band.

The amplifier matching networks and chassis are shown in Drawings 1261666, 1261667, and 1261661; the schematic is shown in Drawing 1261662.

4. POWER AMPLIFIER SECTION

The power amplifier consists of

- hybrid dividers
- hybrid combiners
- power stages
- output isolator
- output filter

The design and specification of these modules are discussed in the following sections.

4.1 HYBRID DIVIDERS

The 2:1 divider modules composing the 4:1 hybrid meet the following specifications:

Coupling	3 db ± .1 db
Frequency band	2.25 ghz ± 50 mhz
Insertion loss	.07 db
Power rating	30 watts @ 20 C
Impedance	50
Standing wave ratio	1.25:1 max.
Isolation	20 db min.

The dividers are of stripline construction using 1/8" thick glass impregnated teflon. The top and bottom substrate drawings for these hybrids are shown in drawings 12611671 and 1261672.

4.2 HYBRID COMBINER

The hybrid 4:1 combiner consists of three 2:1 combiners meeting specifications as shown in section 4.1. The substrate views are drawings 1261669 and 1261670.

4.3 POWER STAGES

The individual power stages consist of an MSC 4005 transistor. They are hybrid combined as shown in the following figure giving 29 watts output and 9.2 db gain.

The total of 4 stages hybrid combined, meet the following specifications:

Frequency band	2.2 - 2.3 GHz
Gain	db
Gain flatness	0.5 db
Max. power out.	watts
Input standing wave ratio	1.5:1 max.
Efficiency	%
Max load mismatch	1.5:1
Power requirements	23-28 vdc

Temperature data on the Solid State S Band Amplifier is shown in Table 4-I.

The power amplifier schematic and matching networks are shown in Drawings 1261663 and 1261665.

4.4 OUTPUT ISOLATOR

The output isolator was tested to and meets the following specifications:

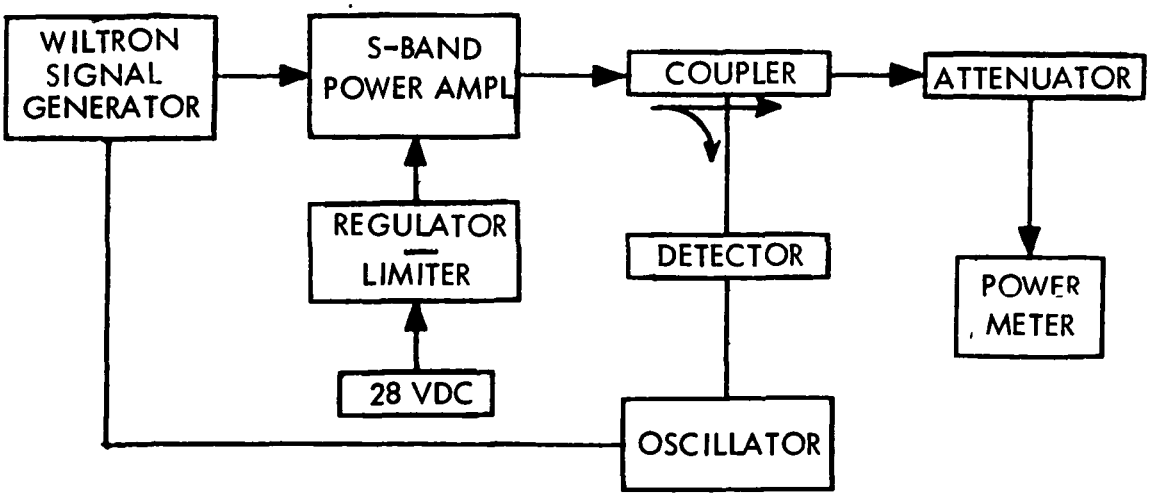
Specifications	
Nominal frequency	2.2 - 2.3 ghz
Bandwidth for 20 db isolation.	100 mhz
Input & output impedance	50 ohms
Standing wave ratio (max.)	1.2
Insertion loss in passband	.25 db max. (at 25 watts)
Load capability	30 watts cw @ 75 C
The above specifications must be met over temp range.	-20 to +70 C
Addington part number	101101203
Probe coupling	-40 db ± 2 db

TABLE 4-I

TEMPERATURE TEST OF SOLID STATE

S-BAND AMPLIFIER

Temp, C	R-F P_{out}, W	Ic, A	Voltage In	Voltage Out	Total Power In, W	Efficiency, %
20	22.8	2.8	28.00	26.83	78.5	29.0
10	22.8	2.8	"	"	78.5	29.0
5	23.6	2.94	"	"	82.2	28.8
0	24.0	2.96	"	"	86.0	28.6
5	24.0	3.00	"	"	84.0	28.6
10	23.7	2.95	"	"	82.55	28.8
15	23.7	2.95	"	"	82.5	28.8
20	23.5	2.95	"	"	82.5	28.5
25	23.1	2.90	"	"	81.5	28.5
30	22.7	2.85	"	"	80.0	28.3
35	22.5	2.85	"	"	80.0	28.2
40	22.1	2.85	"	"	80.0	27.7
45	22.0	2.84	"	"	79.5	27.7
50	21.5	2.81	"	"	79.0	27.5
55	21.4	2.78	"	"	78.0	27.3
60	21.0	2.77	"	"	77.5	27.2
65	20.8	2.74	"	"	76.8	27.2
70	20.3	2.72	"	"	76.0	26.8
75	20.2	2.72	"	"	76.0	26.7



Test Set-Up, Block Diagram

4.5 OUTPUT BANDPASS FILTER

The specifications given below ensure that the system will have the required -95 dbm/ 10 mhz noise floor at 2104 mhz with 5 db margin to allow for excess drive conditions.

Center freq	2.25 ghz
Passband	2.2 to 2.3 mhz
Ripple	0.2 db
Attenuation	45 db at 2.104 ghz ± 5 mhz
	40 db from 4.0 to 10 ghz
Insertion loss	0.4 db msx., target 0.25
Input standing wave ratio	1.25:1
Power capability	30 watts max.
Phase deviation from linear	± 6 degrees over the 100 mhz band
Temperature	-20 to +70 C
Reliability	10^8 hrs.

The filter was tested to and meets these specifications. The outline drawing for the filter is shown in 1261674.

5. VOLTAGE AND CURRENT LIMITER

The voltage and current limiter is shown in figure 5-1. It provides voltage limiting to a maximum of 27.3 vdc by a saturated series transistor. Current limiting is provided by a monostable multivibrator triggered by an excess current flow and acting as crowbar to reduce the voltage to zero and protect the series pass transistor. The regulator will recover automatically upon removal of the overload.

The voltage limiter--current limiter was tested and performed satisfactory. The total drop across the regulator was measured 1.15 volts. A 6 ampere current tripped the current limiter. It reset automatically when the current was reduced to normal. The voltage limiter was set to an upper limit of 28 volts and remained exactly 28 volts for inputs up to 40 volts.

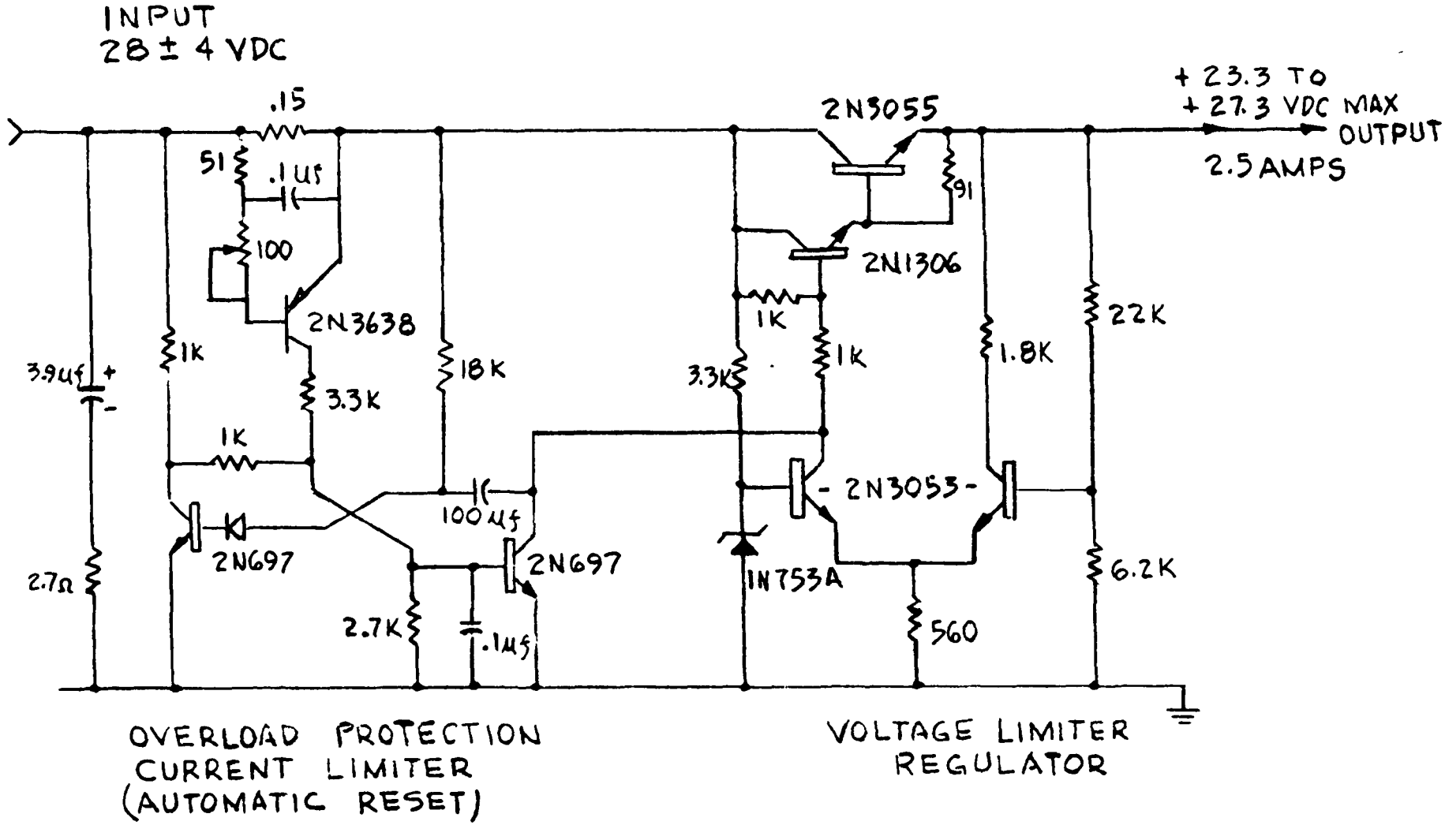


FIGURE 5-1

POWER REGULATOR VOLTAGE LIMITER

6. TEST PROGRAM

The following document lists all test procedures which adequately verify that the breadboard will meet specification requirements. These test procedures are submitted to MSFC for approval in compliance with Exhibit A Scope of Work, Contract No. NAS8-28763.

6.1 LIST OF TESTS REQUIRED AND SPECIFICATION LIMITS

	Test Description	Specification
6.1.1	Input standing wave ratio	1.3:1 (17.8 db return loss)
	Output standing wave ratio (without drive)	1.5:1 (14 db return loss)
6.1.2	Power output (2.25 ghz)	20 watts min.
6.1.3	D-C power input	95 watts max.
6.1.4	Input overdrive (R-F)	1 watt max.
	Normal drive	25-50 mwatts
6.1.5	Bandwidth (± 1 db)	100 mhz
6.1.6	Output noise	-95 dbm of 2104 mhz, 10 mhz band
6.1.7	Spurious outputs	60 db below carrier within 4 mhz band centered at 2.250.5 mhz
6.1.8	Temperature (Meeting performance requirements)	-20 to +70 C

6.2 DESCRIPTION OF TESTS

The test equipment shown in the block diagram are suggested and alternate equipment can be used.

6.2.1 Input, Output Standing Wave Ratio

To measure input and output impedances, a Wiltron 610-C Signal Generator and Narda Directional Coupler were set up as shown in Figure 6-1. Measurements are fast

and accurate; the Narda High Directivity Coupler has a directivity of greater than 40 db from 10 yo 3500 mhz and the accuracy of the readout (Return Loss) is ±0.3 db.

6.2.2 Power Output

The power output is measured using a Thermoelectric calorimeter power meter. The power into the calorimeter is reduced using calibrated attenuators as shown in Figure 6.2.

For the overdrive test, a travelling wave tube Servo 2220 is used to amplify the output of the signal generator and provide 1 watt to the input of the S-Band power amplifier. The normal input is 25-50 mwatts at 2.25 ghz.

6.2.3 D-C Power Input

The input power is measured accurately using a digital voltmeter and a millimeter. Since the power input can be calculated at 28 ± 4 vdc, the efficiency can also be calculated using the set up shown in Figure 6.3.

6.2.4 Input Overdrive

According to specification, the S-Band amplifier should survive 1 watt overdrive. This drive is derived using a travelling wave tube amplifier following the signal generator as shown in Figure 6.2. During overdrive all parameters are monitored.

6.2.5 Bandwidth

The instantaneous bandwidth is measured using a Wiltron sweep generator as shown in Figure 6.3 set-up. The detected output is displayed on the calibrated screen of the oscilloscope for the nominal input power of 25 watts. A frequency counter is provided to calibrate the marker of the sweep generator. Photos can be taken of the 100 mhz bandwidth or greater to shown the bandpass characteristic of the amplifier filter.

6.2.6 Output Noise

Measurement of noise at 2104 mhz is accomplished using a spectrum analyzer and applying the necessary correction factors. This measurement has to be performed under signal conditions in order to excite the class-C power amplifiers. Only 10 db of attenuation is used at the output of the amplifier in order to maintain a margin since the noise level of the spectrum analyzer at 2.1 ghz is -117 dbm. To prevent overloading of the spectrum analyzer, a bandpass filter is used at 2104 mhz refecting the 2.25 ghz output signal by at least 40 db. The set-up is shown in Figure 6.4. The yig filter is set manually to 2104 mhz.

6.2.7 Spurious Outputs

Spurious outputs within a bandwidth of 4 mhz centered at 2,250.5 mhz is measured using the spectrum analyzer and necessary attenuator to reduce the level and prevent overloading of the spectrum analyzer. The set-up is shown in Figure 6.5.

6.2.8 Temperature

The set-up of Figure 6.6 is used for the temperature test. All monitoring cables are brought out and continues monitoring of chassis temperature and power output is performed during the temperature variation. As shown all performance requirement can be checked during the test.

6.3 TEST DATA SHEET

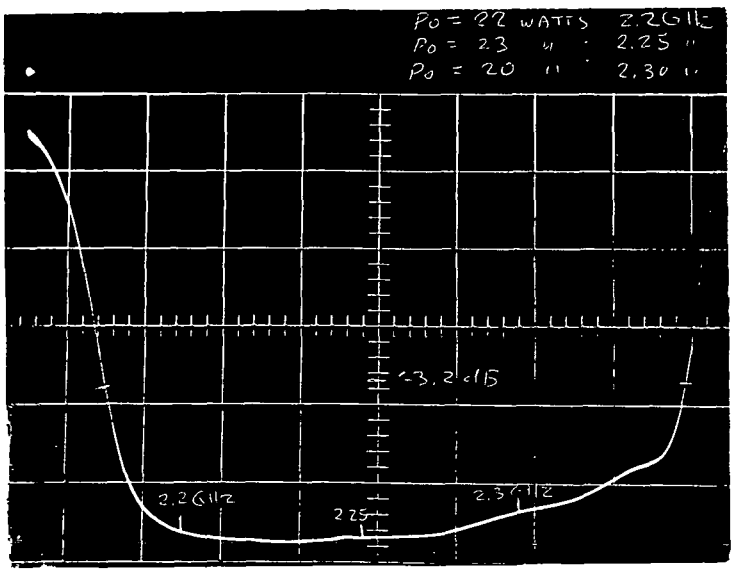
(a)	Input standing wave ratio	1.28	(18 db return loss)
(b)	Output standing wave ratio	1.12	(25 db return loss)
(c)	Pout (2.25 ghz)	23.0	watts
(d)	Pin - Vin	28.14	volts
	Iin	2.9	amperes
	Pin	81.0	watts
(e)	Output Noise	* >87	dbm/10 mhz
(f)	Spurious Output	No Spurs >70	db at 2250.5 mhz

* Limited by Spectrum Analyzer

ITTDCD Engineering Michael D. Lynch Date 8/15/73

ITTDCD Quality Assurance E. Baranyi Date 8/15/73

(g) Bandwidth



Photograph
(Instantaneous Bandwidth)

ITTDCD Engineering Michael D. Yamakoshi Date 8/15/73

ITTDCD Quality Assurance E. Barajas Date 8/15/73

6.4 LIST OF TEST EQUIPMENT REQUIRED

1. Attenuator, 20 db, 10 db, 50 watt; Narda Model 765-20, 765-10.
2. Attenuator, 20 db, 2 watt, Weinschell Model 50-20.
3. Attenuator, Variable 0 to 20 db, Narda Model 792 FM.
4. Clip-on millimeter 0 to 10 amps, Hewlett Packard Model 428B.
5. Crystal Detector, Hewlett Packard Model 423A.
6. Digital Voltmeter, Hewlett Packard Model 3440A.
7. DC Multifunction unit, Hewlett Packard Model 3444A.
8. Frequency counter, Systron Donner Model 6316A.
9. Thermoelectric Calorimeter Model N-685-2 PRD.
10. Power Meter Model 6685 PRD.
11. Signal Generator, S-Band, Hewlett Packard Model 8616A.
12. Sweep Generator, Frame Model 610C, Head 6112C Wiltron.
13. Tektronix Model 531A.
14. ~~VSWR Autotester, Mode 63N50 Wiltron.~~
15. ~~Logarithmic Level Meter Model 501 Wiltron.~~
16. Power Supply, Lamba Model LH125 FM.
17. Spectrum Analyzer

    RF Section Model 8555A Hewlett Packard

    IF Section Model 8552A Hewlett Packard

    Display Section Model 141 S Hewlett Packard

    Automatic Preselector Model 8445 Hewlett Packard
18. Directional Coupler, Model 3043-20 Narda.
19. Traveling Wave Tube Amplifier, Model 2220 Servo Microwave Amplifier.

Note 1: Item 14 was deleted prior to test

Item 15 was changed to NARDA 3093 High Directivity Coupler.

Note 2: All equipment used for this test was under current calibration.

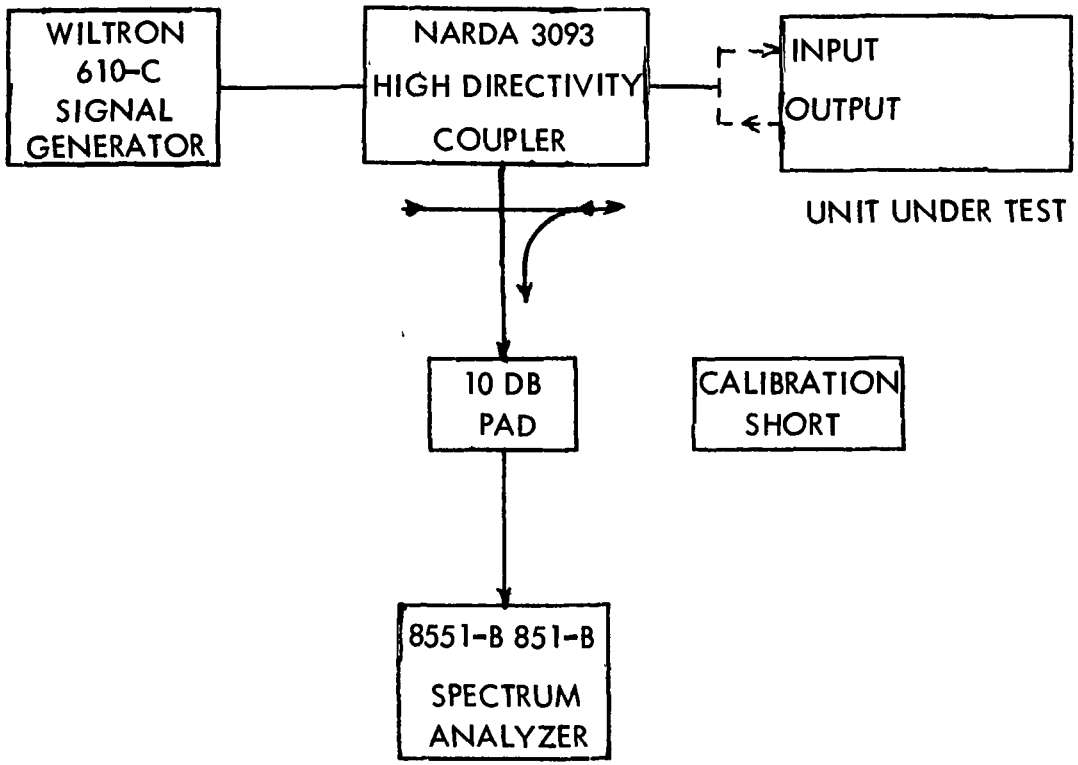


Figure 6.1 Input & Output Standing Wave Ratio

DRAWING NUMBER

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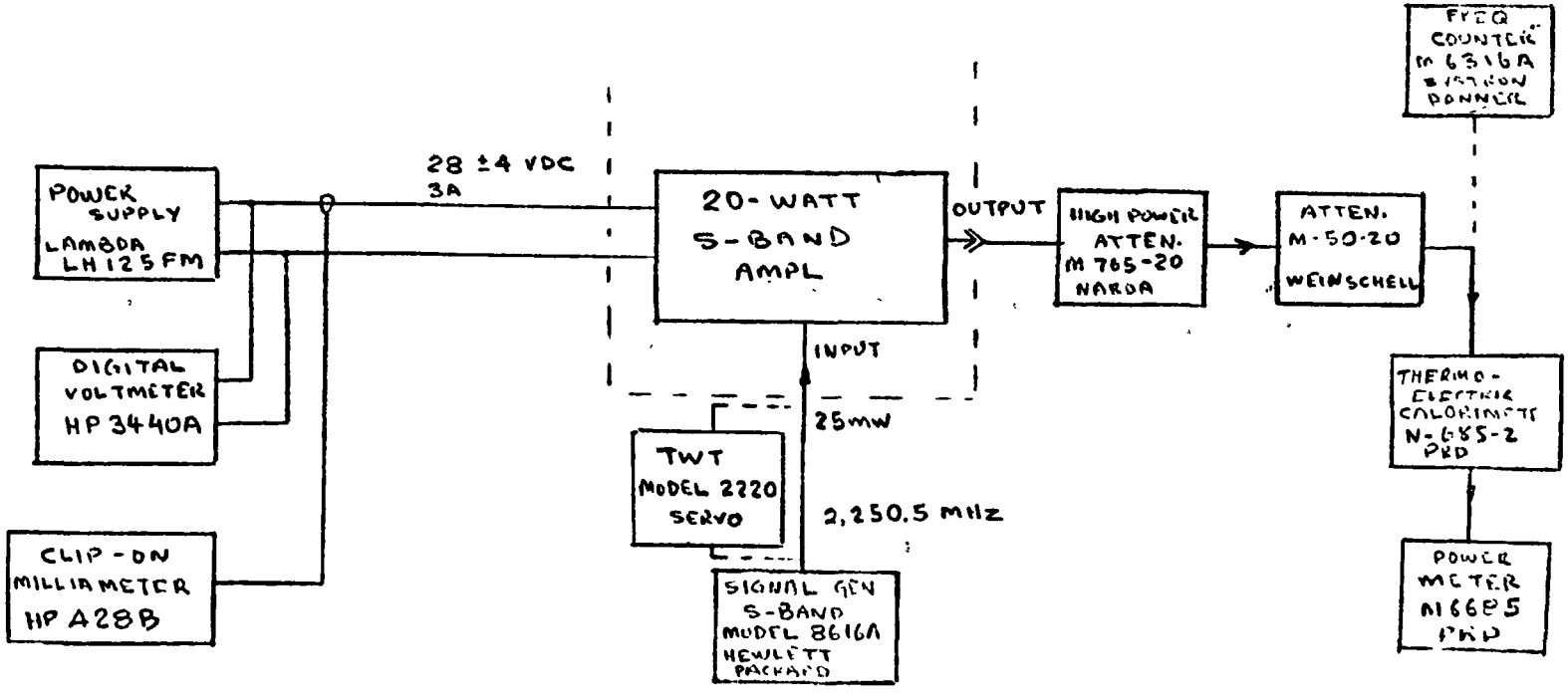
SIZE A | CODE IDENT NO. 28528 | DWG. NO.

REV.

SHEET 20



POWER OUTPUT AND EFFICIENCY MEASUREMENTS

PLUS INPUT OVERDRIVE

FIG 6.2

6.2

ITT DEFENSE COMMUNICATIONS DIVISION NUTLEY, NEW JERSEY

DRAWING NUMBER

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SIZE A

CODE IDENT NO. 28528

DWG. NO

REV.

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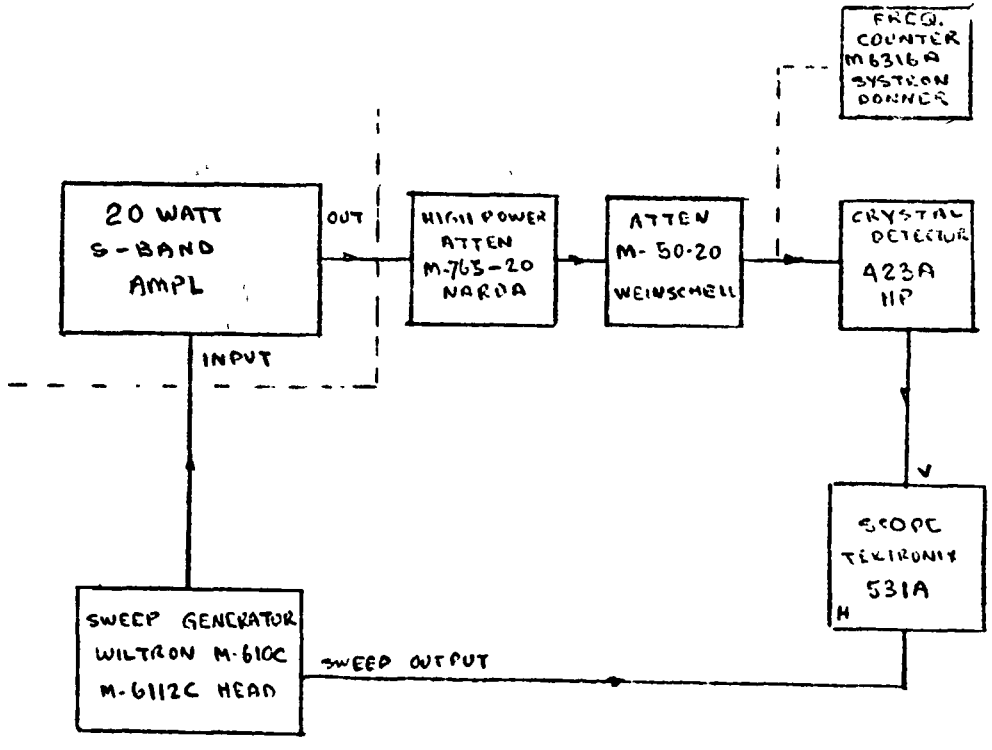

BAND WIDTH MEASUREMENT, SWEPT

6.3

FIGURE 6.3

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SIZE A

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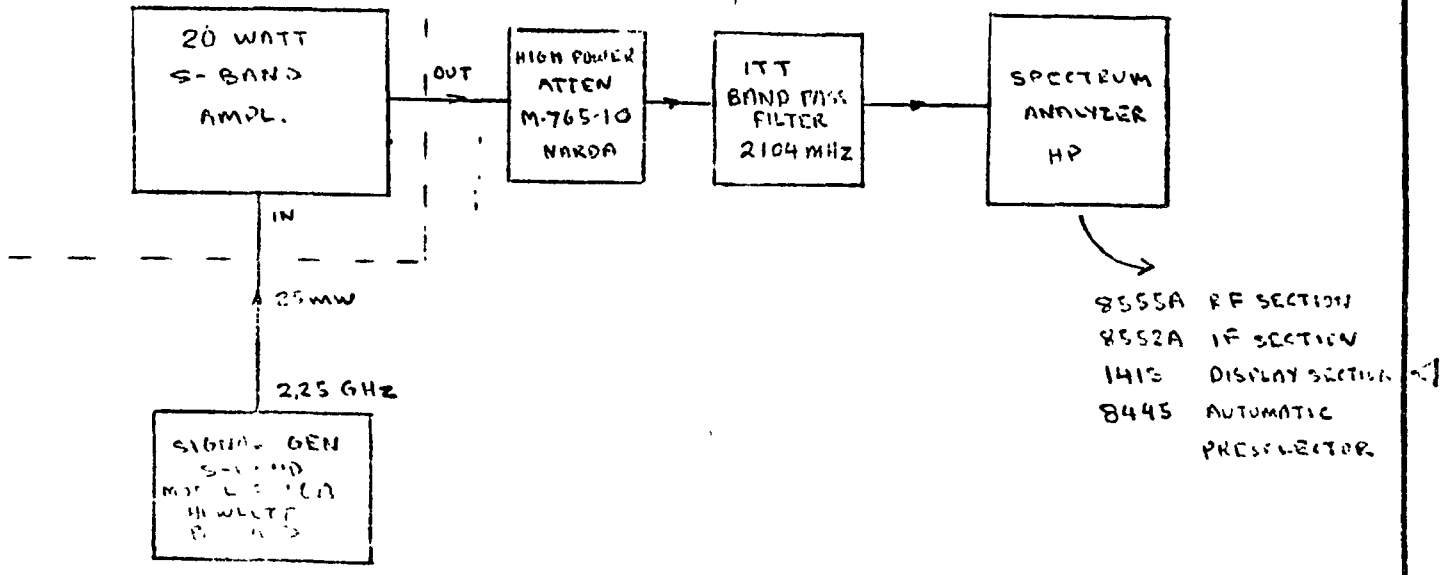

MEASUREMENT OF OUTPUT NOISE LEVEL AT 2104 MHz

FIGURE 6.4

4

DRAWING NO.

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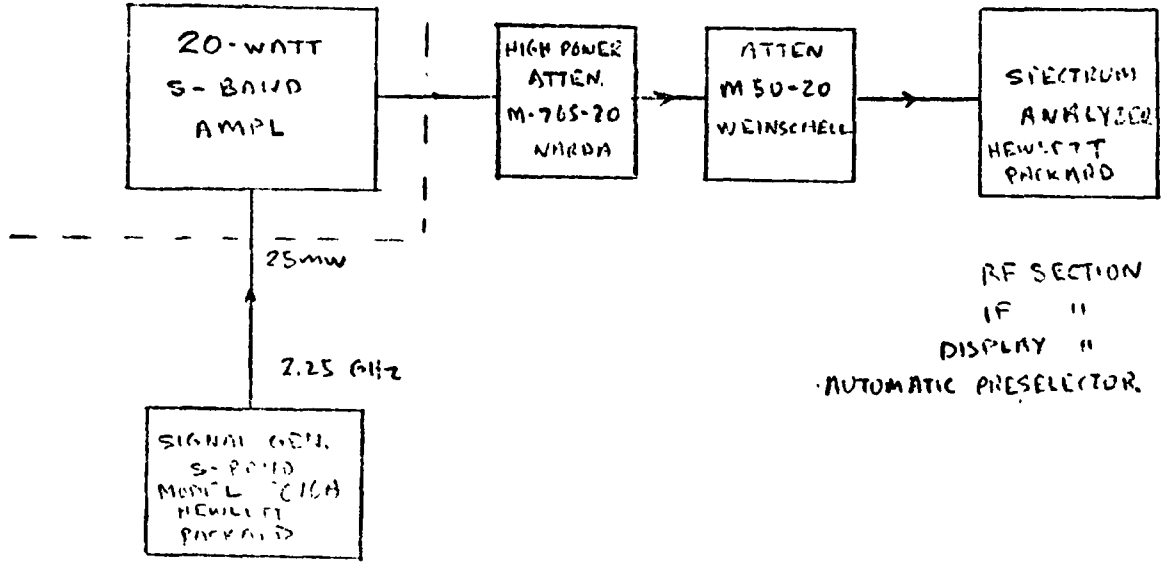
CODE IDENT NO. 28528

DWG. NO. -

REV.

SHEET 23



MEASUREMENT OF SPURIOUS OUTPUTS

FIGURE 6.5

DRAWING NUMBER

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SIZE A

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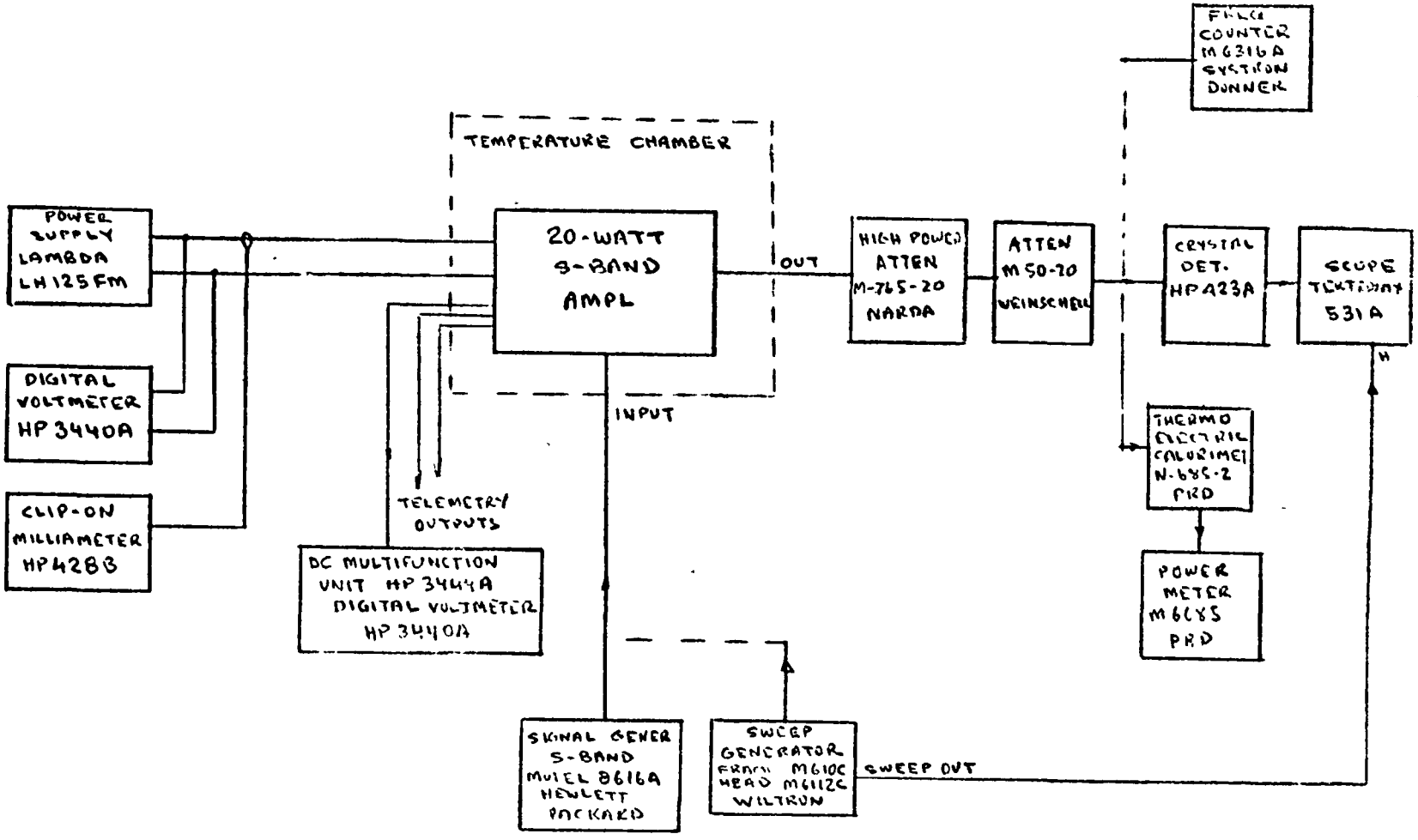
REV.

SHEET 24



TEMPERATURE TEST, TELEMETRY OUTPUTS PLUS TURN-OFF CAPABILITY.

FIGURE 6.6

6.2

LIST OF DRAWINGS

The following drawings are bound in order and referred to by drawing number:

1261674 Bandpass Filter Outline

~~1261673 Mechanical Layout~~

1261672 90 Degree Input Hybrids (Top)

1261671 90 Degree Input Hybrids (Bottom)

1261670 90 Degree Output Hybrids (Top)

1261669 90 Degree Output Hybrids (Bottom)

1261664 Telemetry & Functions, Circuit Diagram

1261668 0.8 Watt Amplifier Matching Networks

1261667 3.5 Watt Amplifier Matching Networks

1261666 Class A Amplifier Matching Networks

1261665 8 Watt Amplifier Matching Networks

1261663 Solid State Power Amplifier, Block Schematic*

1261662 Solid State Driver Amplifier, Block Schematic*

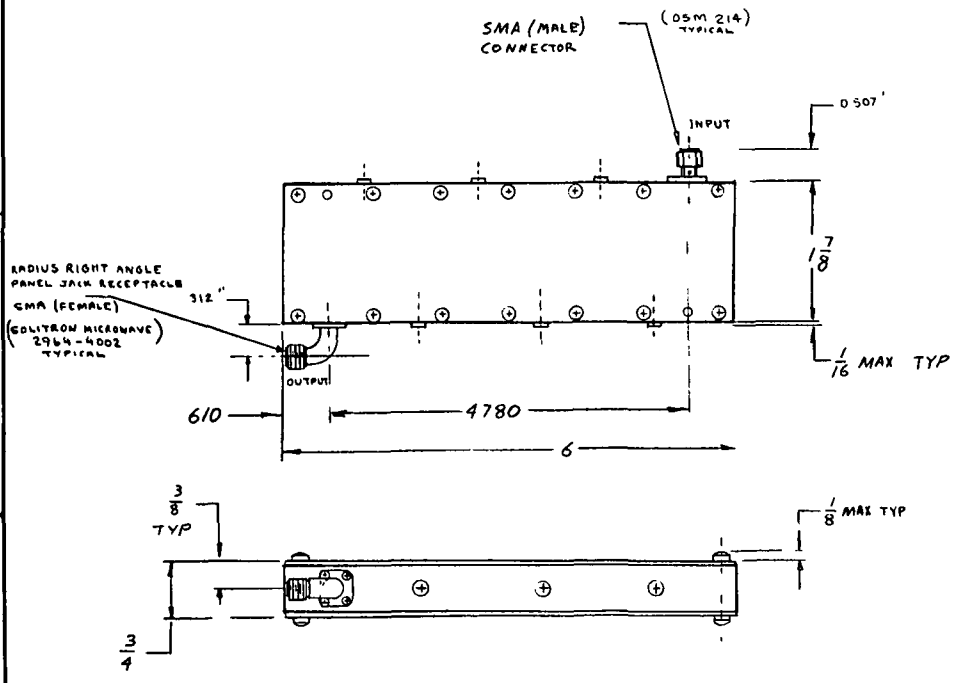
1261661 Driver Amplifier Chassis

1261659 Power Amplifier Chassis

1261673-B Engineering Sketch of Main Frame

*Sheets 2, 3, and 4 of both Drawings are parts lists; because of size differences, these are bound following the package of C Size Drawings.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		— ORIGINAL ISSUE		



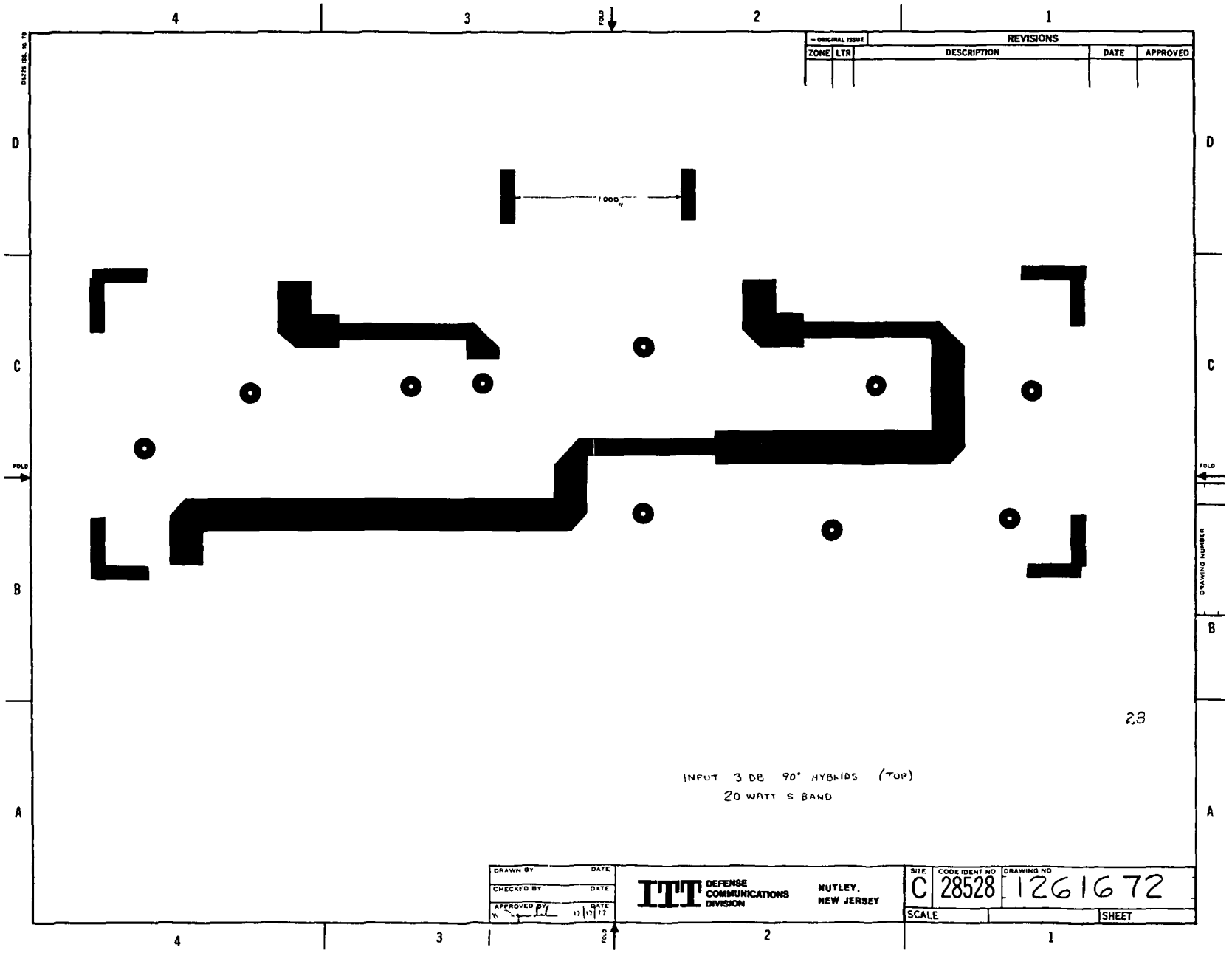
SPECIFICATIONS, ELECTRICAL

BAND PASS	22 - 23 GHz
MID BAND INSERTION LOSS	0.4 DB MAX
BAND EDGES INSERTION LOSS	0.65 DB MAX
REJECTION AT 21 GHz	45 DB MIN
REJECTION 4 TO 10GHz	40 DB MIN
INPUT/OUTPUT IMPEDANCE	50 OHMS
PASS BAND FLATNESS	0.2 DB
INPUT/OUTPUT VSWR	1.25 1 MAX
PHASE DEVIATION FROM LINEARITY	±6 DEGREES OVER 100 MHz
OPERATING TEMPERATURE	-20°C TO +70°C

BAND PASS FILTER OUTLINE
(22 - 23 GHz)

26

DRAWN BY	DATE	ITT DEFENSE COMMUNICATIONS DIVISION NUTLEY, NEW JERSEY	SIZE C	CODE IDENT NO 28528	DRAWING NO 1261674
CHECKED BY	DATE		SCALE		SHEET 26
APPROVED BY [illegible]	DATE 12/17/72				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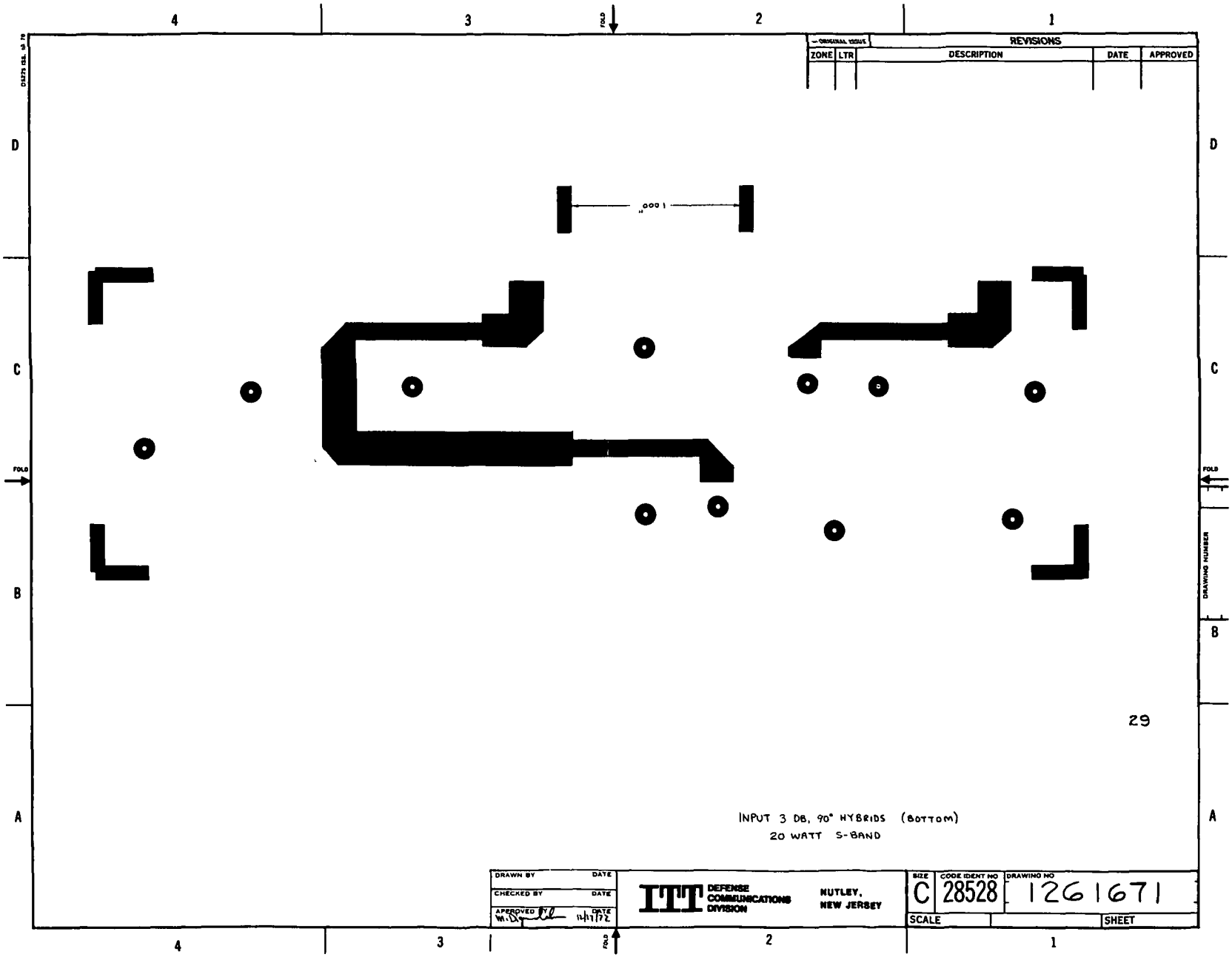
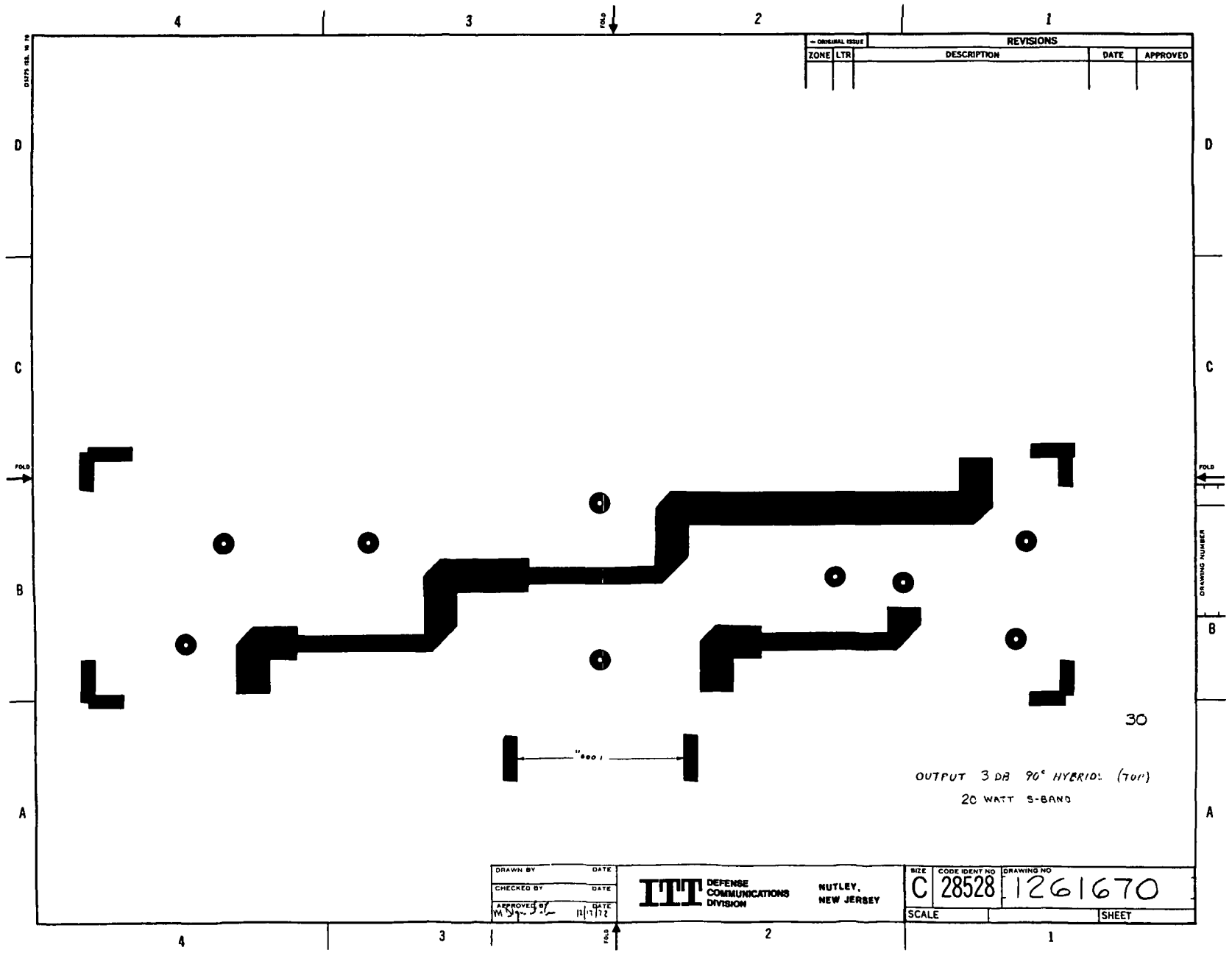
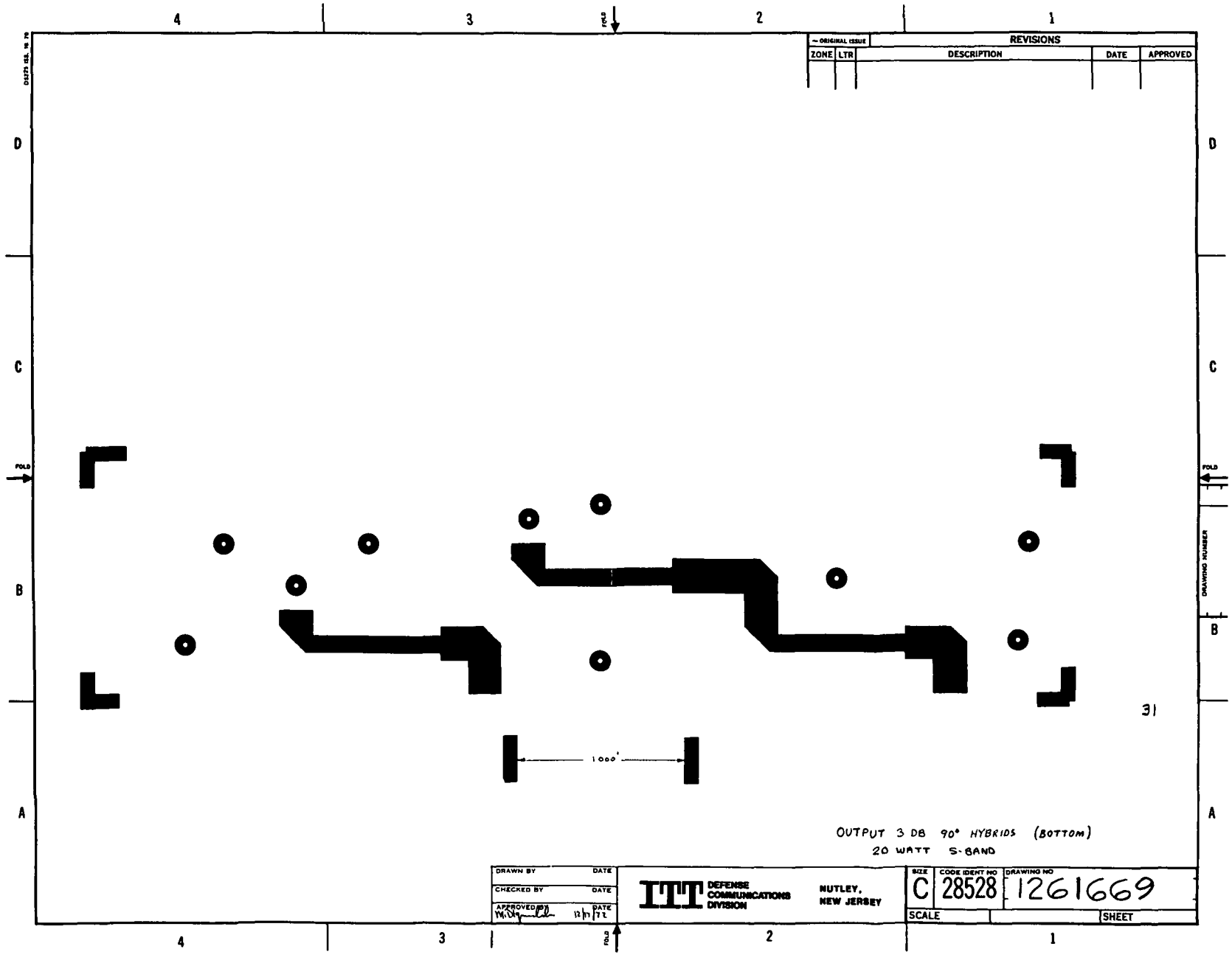
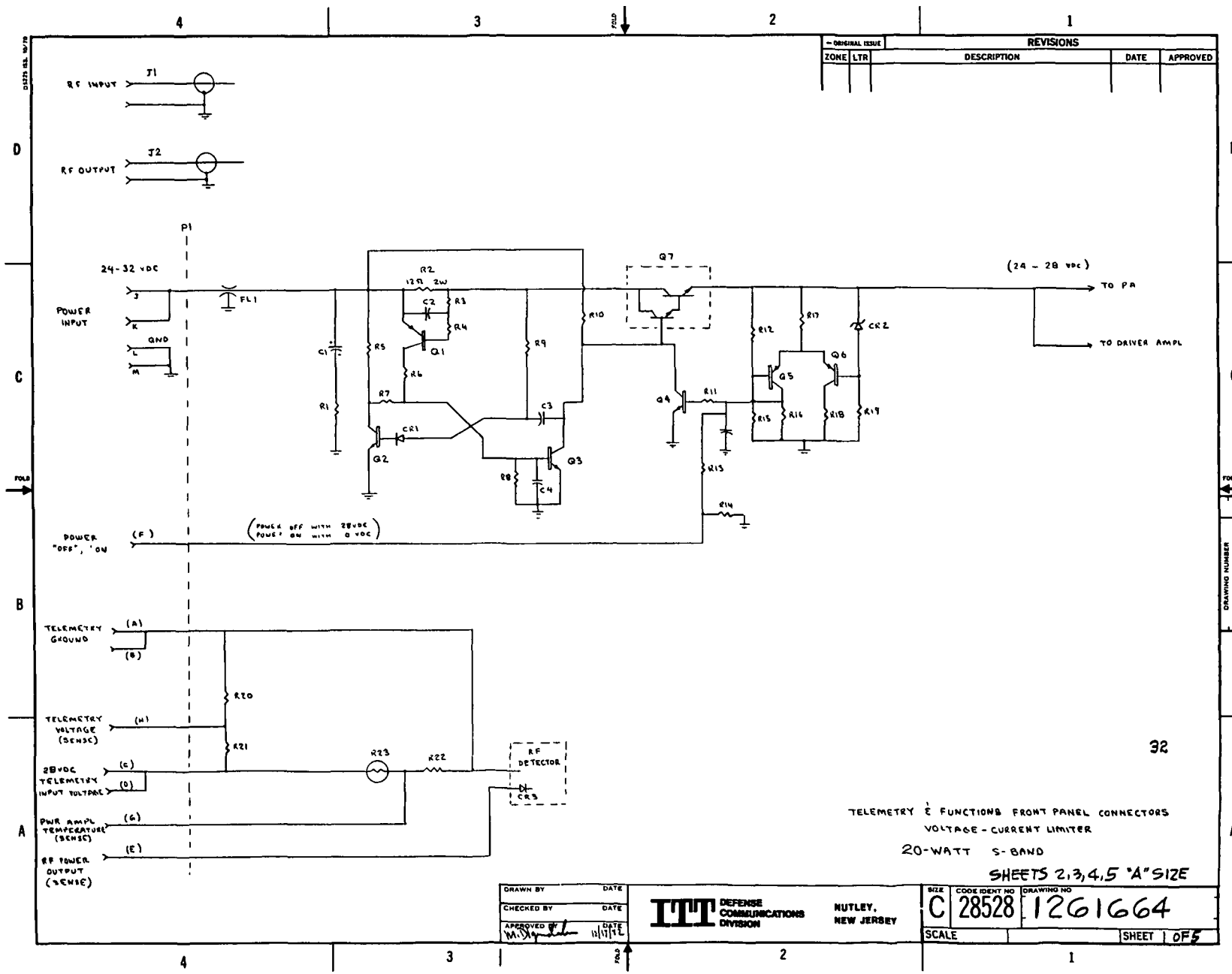
1000
FOLD
DRAWING NUMBER
28
INPUT 3 DB 90° HYBRIDS (TOP)
20 WATT S BAND
DRAWN BY
DATE
CHECKED BY
DATE
APPROVED BY
DATE
12/17/72
ITT DEFENSE COMMUNICATIONS DIVISION
NUTLEY, NEW JERSEY
SIZE
C
CODE IDENT NO
28528
DRAWING NO
1261672
SCALE
SHEET


4
3
2
1
D
C
B
A
FOLD
.0001"
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
29
INPUT 3 DB, 90° HYBRIDS (BOTTOM)
20 WATT S-BAND
DRAWN BY
DATE
CHECKED BY
DATE
APPROVED
DATE
11/17/72
ITT DEFENSE COMMUNICATIONS DIVISION
NUTLEY, NEW JERSEY
SIZE
C
CODE IDENT NO
28528
DRAWING NO
1261671
SCALE
SHEET

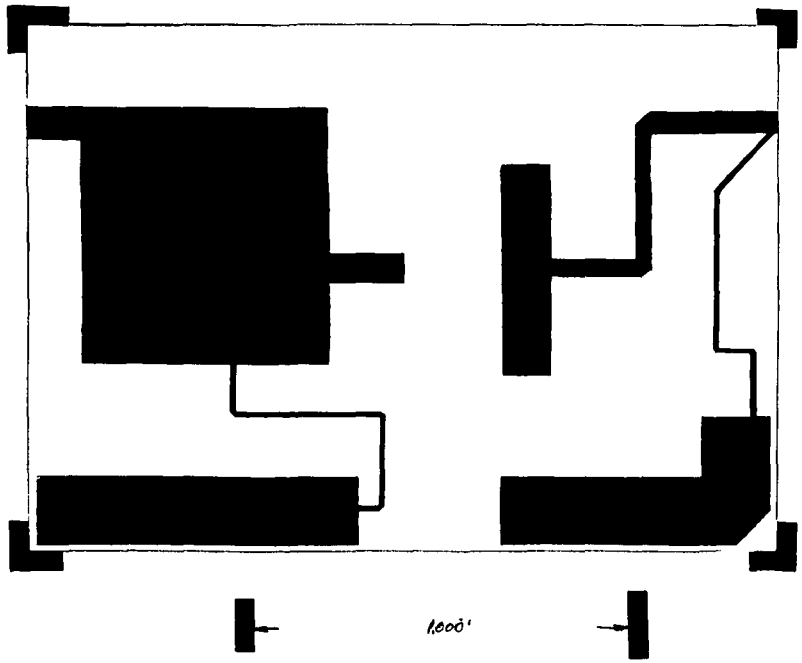

REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
30
OUTPUT 3 DB 90° HYBRID (TOP)
20 WATT S-BAND
DRAWN BY
DATE
CHECKED BY
DATE
APPROVED BY
12/17/72
ITT DEFENSE COMMUNICATIONS DIVISION
NUTLEY, NEW JERSEY
SIZE
C
CODE IDENT NO
28528
DRAWING NO
1261670
SCALE
SHEET


4
3
2
1
D
C
B
A
FOLD
REVISIONS
~ ORIGINAL ISSUE
ZONE
LTR
DESCRIPTION
DATE
APPROVED
DRAWING NUMBER
1.000"
31
OUTPUT 3 DB 90° HYBRIDS (BOTTOM)
20 WATT S-BAND
DRAWN BY
DATE
CHECKED BY
DATE
APPROVED BY
DATE
12/7/72
ITT DEFENSE COMMUNICATIONS DIVISION
NUTLEY, NEW JERSEY
SIZE
C
CODE IDENT NO
28528
DRAWING NO
1261669
SCALE
SHEET


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
RF INPUT
J1
RF OUTPUT
J2
P1
24-32 VDC
POWER INPUT
J
K
GND
L
M
FL1
R2
12Ω 2W
C2
R3
R4
Q1
C1
R5
R6
R1
R7
CR1
Q2
C3
Q3
R8
C4
R9
R10
Q7
Q4
R11
R13
R14
R12
R17
CR2
Q5
Q6
R15
R16
R18
R19
(24 - 28 VDC)
TO PA
TO DRIVER AMPL
POWER "OFF", "ON
(F)
(POWER OFF WITH 28VDC
POWER ON WITH 0 VDC)
TELEMETRY GROUND
(A)
(B)
R20
TELEMETRY VOLTAGE (SENSE)
(H)
R21
R23
R22
RF DETECTOR
CR3
28VDC TELEMETRY INPUT VOLTAGE
(C)
(D)
PWR AMPL TEMPERATURE (SENSE)
(G)
RF POWER OUTPUT (SENSE)
(E)
32
TELEMETRY & FUNCTIONS FRONT PANEL CONNECTORS
VOLTAGE - CURRENT LIMITER
20-WATT S-BAND
SHEETS 2,3,4,5 "A" SIZE
DRAWN BY DATE
CHECKED BY DATE
APPROVED BY DATE 11/11/72
ITT DEFENSE COMMUNICATIONS DIVISION
NUTLEY, NEW JERSEY
SIZE C
CODE IDENT NO 28528
DRAWING NO 1261664
SCALE
SHEET 1 OF 5
DRAWING NUMBER
FOLD

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		— ORIGINAL ISSUE		

S-
OLID



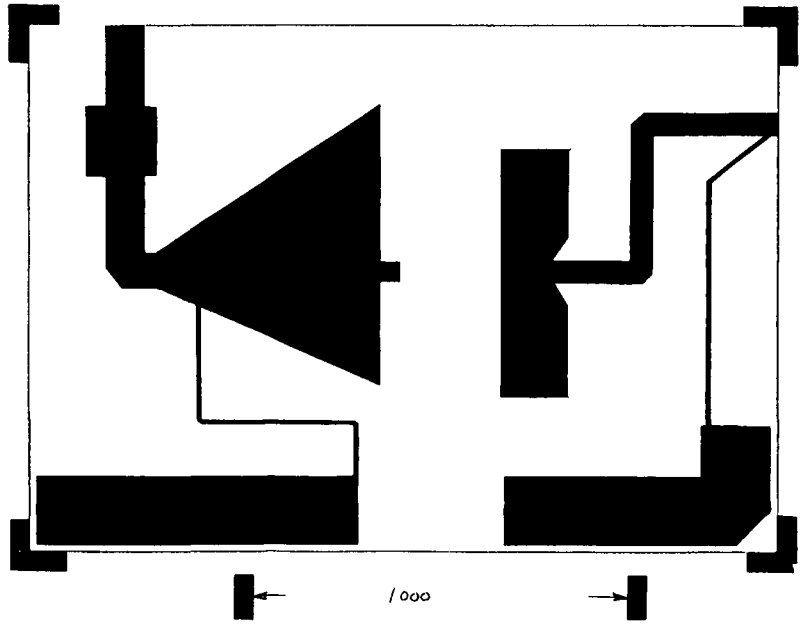
33

0 8 WATT AMPLIFIER MATCHING NETWORKS
20-WATT S-BAND

DRAWN BY	DATE	ITT DEFENSE COMMUNICATIONS DIVISION	NUTLEY, NEW JERSEY	SIZE C	CODE IDENT NO 28528
CHECKED BY	DATE			SCALE	SHEET
APPROVED BY M. Dia	DATE 12/1/72				

DRAWING NO 1261668

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		— ORIGINAL ISSUE		



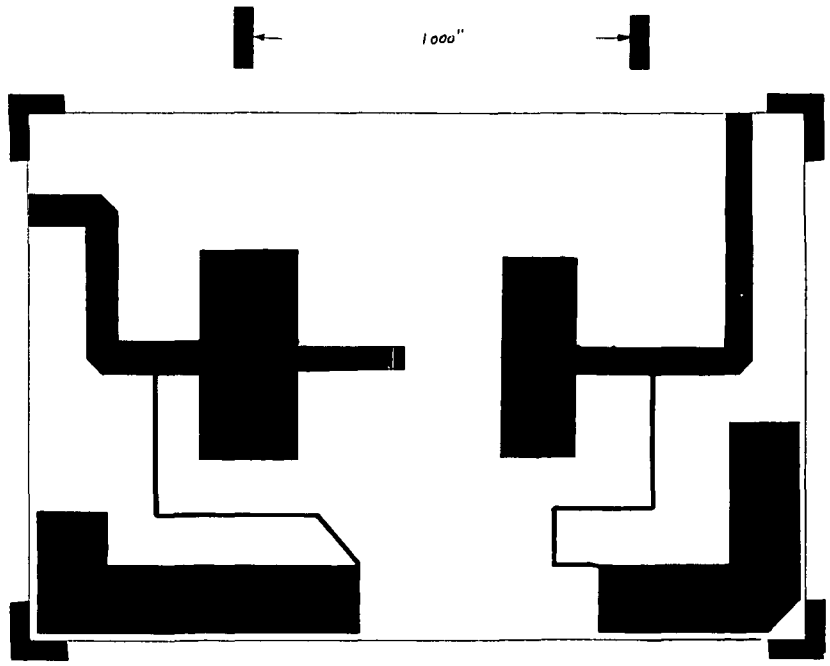
34

3.5 WATT AMPLIFIER MATCHING NETWORKS
20-WATT S-BAND

DRAWN BY	DATE	ITT DEFENSE COMMUNICATIONS DIVISION	NUTLEY, NEW JERSEY	SIZE C	CODE IDENT NO 28528
CHECKED BY	DATE			SCALE	SHEET
APPROVED BY M. Dagnall	DATE 12/17/72				

DRAWING NO 1261667

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
— ORIGINAL ISSUE				



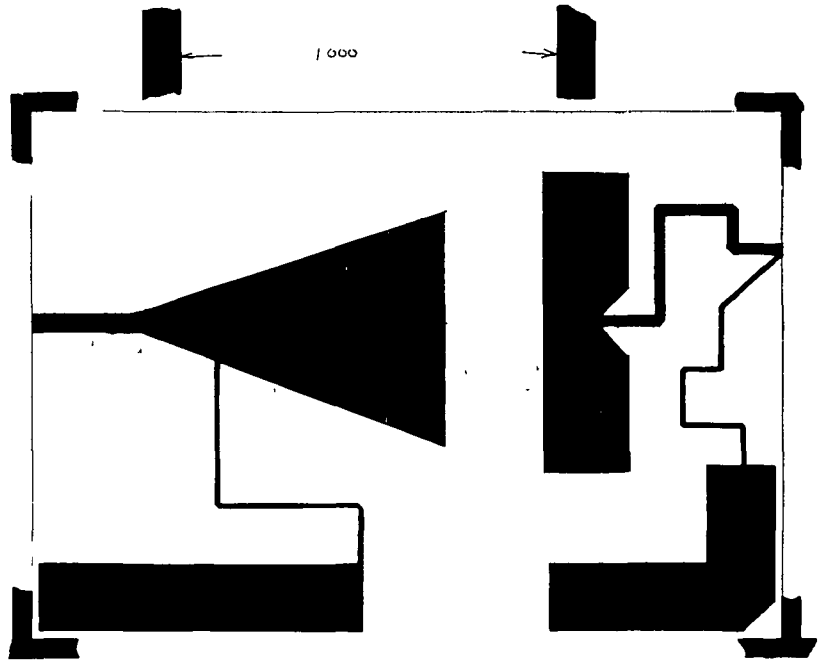
35

CLASS-A AMPLIFIER MATCHING NETWORKS

20-WATT S-BAND

DRAWN BY / DATE	ITT DEFENSE COMMUNICATIONS DIVISION	NUTLEY, NEW JERSEY	SIZE C	CODE IDENT NO 28528	DRAWING NO 1261666
CHECKED BY / DATE			SCALE		SHEET
APPROVED BY W. [illegible] / DATE 12/17/72					

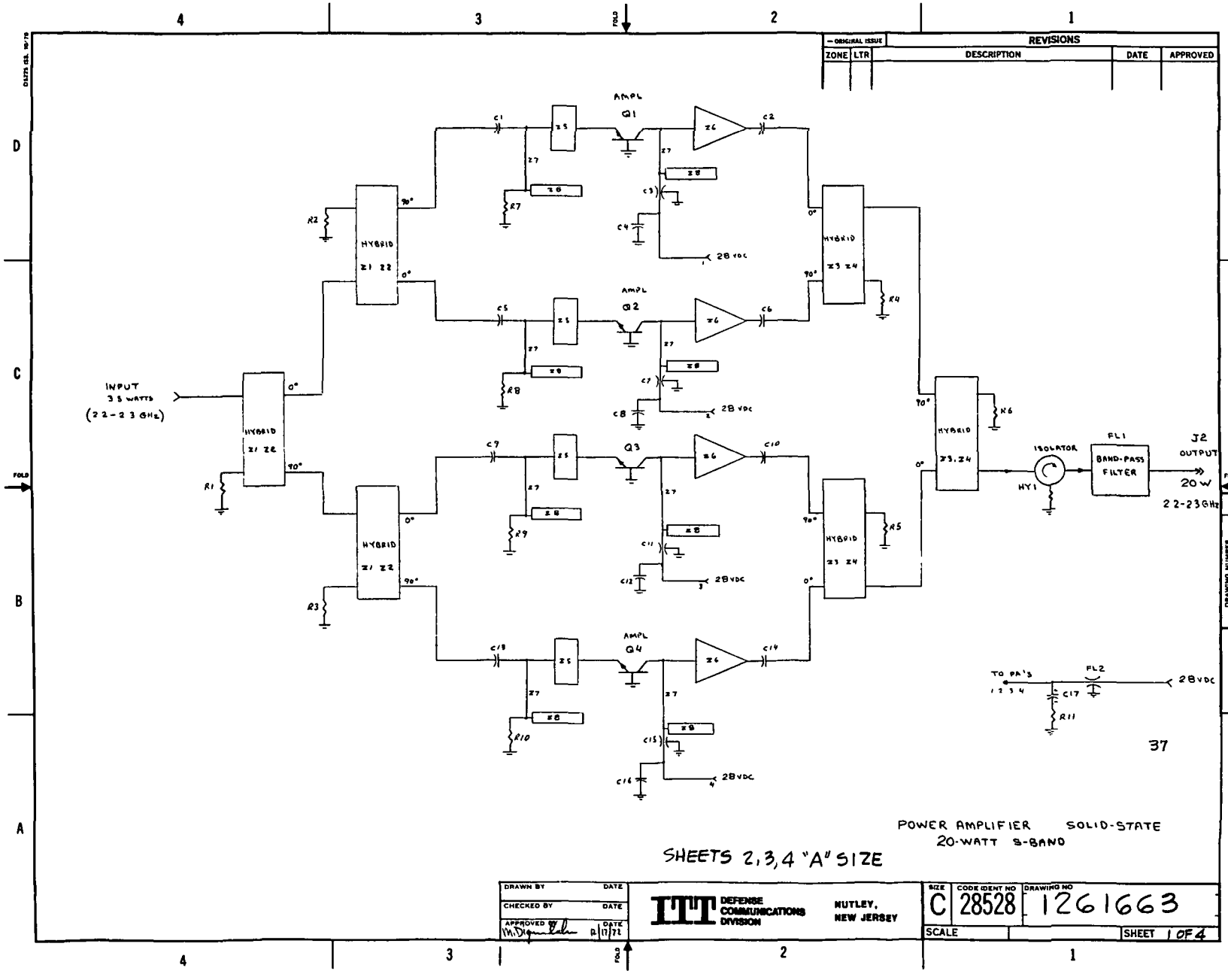
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		— ORIGINAL ISSUE		



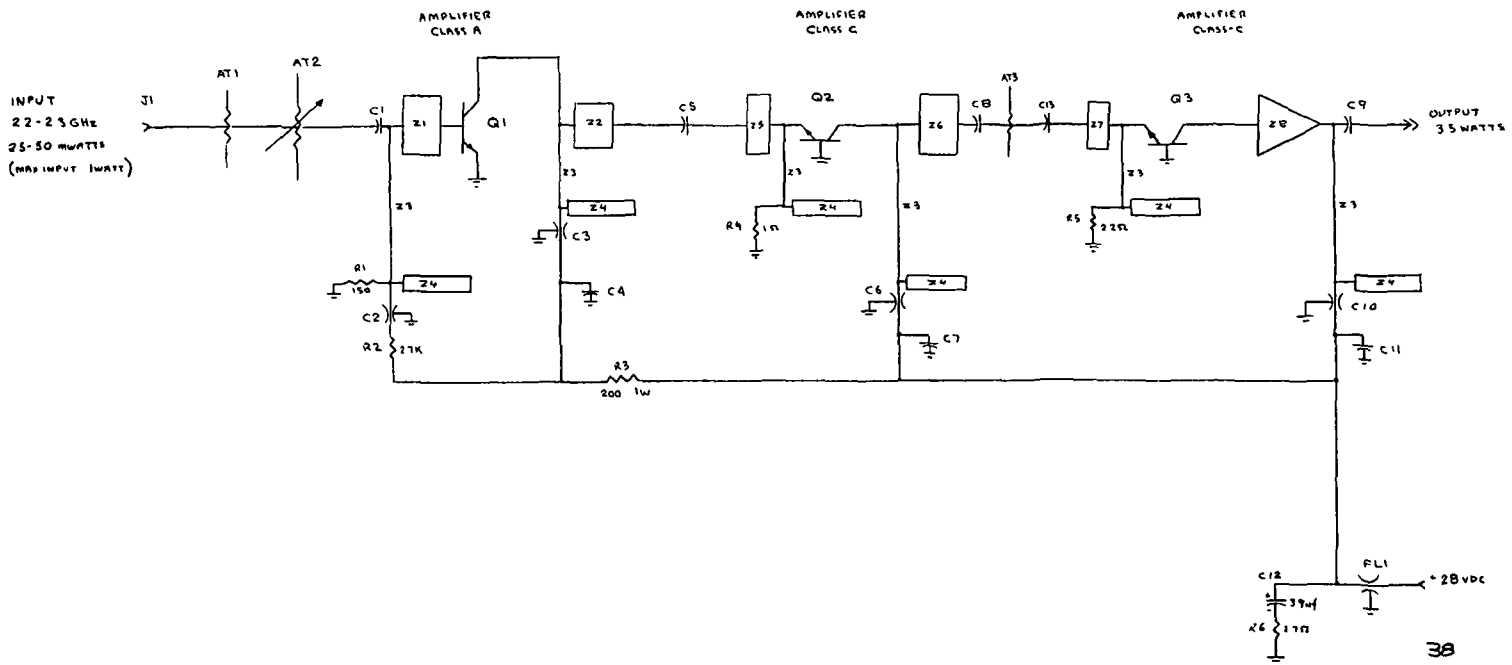
36

8-WATT AMPLIFIER MATCHING NETWORKS
20-WATT S-BAND

DRAWN BY / DATE	ITT DEFENSE COMMUNICATIONS DIVISION	NUTLEY, NEW JERSEY	SIZE C	CODE IDENT NO 28528
CHECKED BY / DATE				DRAWING NO 1261665
APPROVED BY M. Dyer / DATE 12/17/72			SCALE	SHEET


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
— ORIGINAL ISSUE
INPUT
3.5 WATTS
(22-23 GHz)
HYBRID Z1 Z2
HYBRID Z3 Z4
AMPL Q1
AMPL Q2
AMPL Q3
AMPL Q4
28 VDC
ISOLATOR
HY1
FL1
BAND-PASS FILTER
J2
OUTPUT
20 W
22-23GHz
TO PA'S 1 2 3 4
FL2
28VDC
37
POWER AMPLIFIER SOLID-STATE
20-WATT S-BAND
SHEETS 2,3,4 "A" SIZE
DRAWN BY DATE
CHECKED BY DATE
APPROVED DATE 12/17/72
ITT DEFENSE COMMUNICATIONS DIVISION
NUTLEY, NEW JERSEY
SIZE C
CODE IDENT NO 28528
DRAWING NO 1261663
SCALE
SHEET 1 OF 4

~ ORIGINAL ISSUE	REVISIONS			
ZONE	LTR	DESCRIPTION	DATE	APPROVED

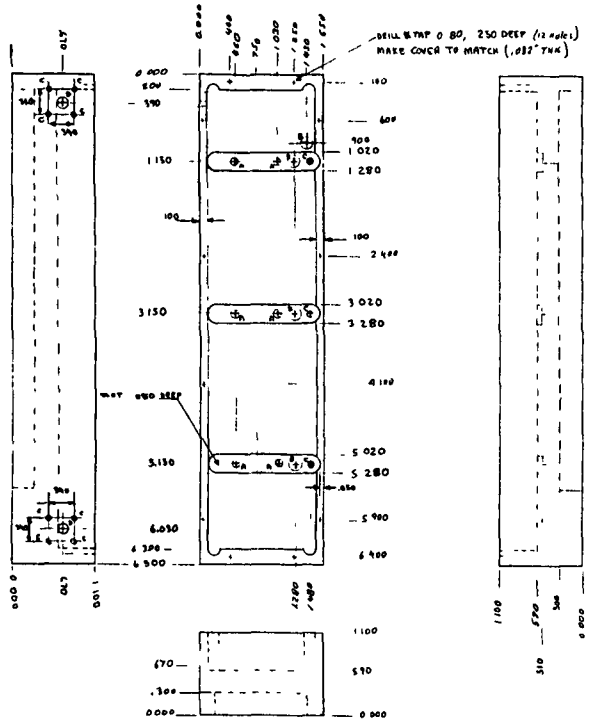


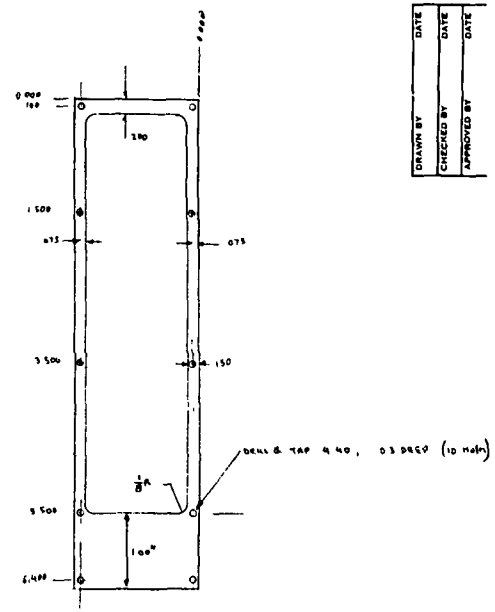
SHEETS 2, 3, 4 "A" SIZE

DRIVER AMPLIFIER SOLID STATE
20-WATT S-BAND

DRAWN BY	DATE				
CHECKED BY	DATE	ITT DEFENSE COMMUNICATIONS DIVISION	NUTLEY, NEW JERSEY	SIZE C	CODE IDENT NO 28528	DRAWING NO 1261662
APPROVED BY	DATE 12/17/73			SCALE	SHEET 1 OF 4

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		— ORIGINAL ISSUE		





	DATE
DRAWN BY	
CHECKED BY	
APPROVED BY	

'A' (HOLES) DRILL THRU & TAP 4-40
'B' (HOLES) DRILL THRU & TAP 8-32
'C' (HOLES) DRILL THRU & TAP 2-56
'D' (HOLES) .166 DIA

39

CHASSIS

DRIVER AMPLIFIER MECHANICAL LAYOUT

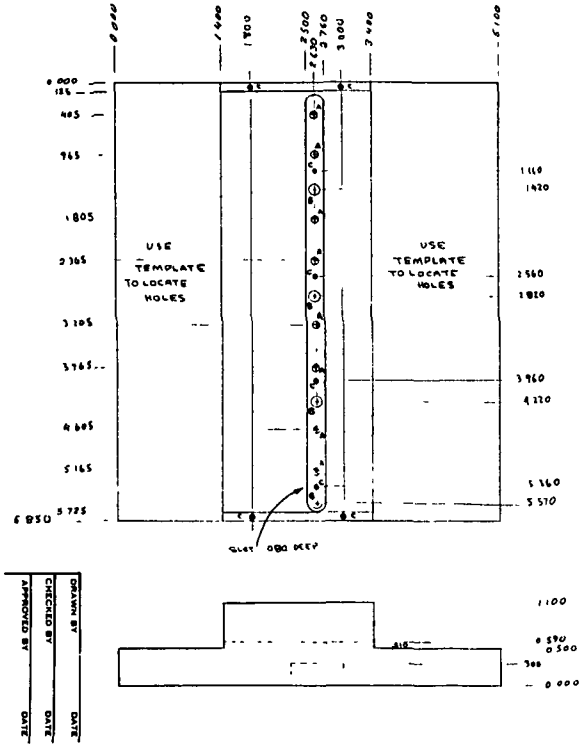
20-WATT S-BAND

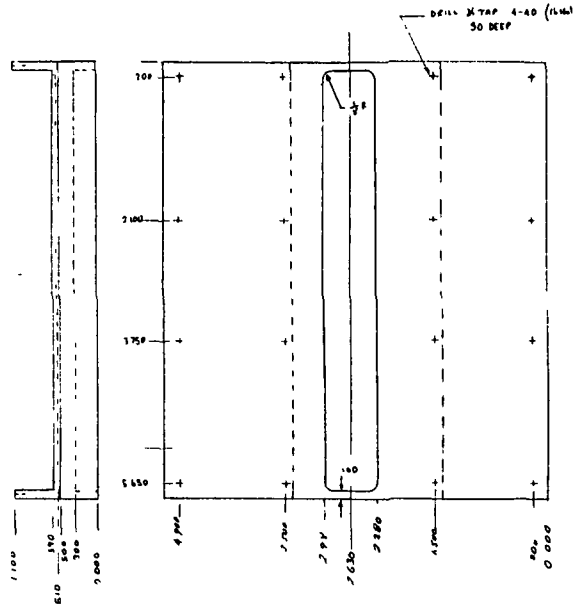
DRAWN BY	DATE	ITT DEFENSE COMMUNICATIONS DIVISION	NUTLEY, NEW JERSEY
CHECKED BY	DATE		
APPROVED BY	DATE 12/17/76		

SIZE	CODE IDENT NO	DRAWING NO
C	28528	1261661
SCALE		SHEET

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		— ORIGINAL ISSUE		

A (HOLE) DRILL THRU & TAP 4-40
B (HOLE) DRILL THRU & TAP 8-32
C (HOLES) DRILL THRU & TAP 2-56





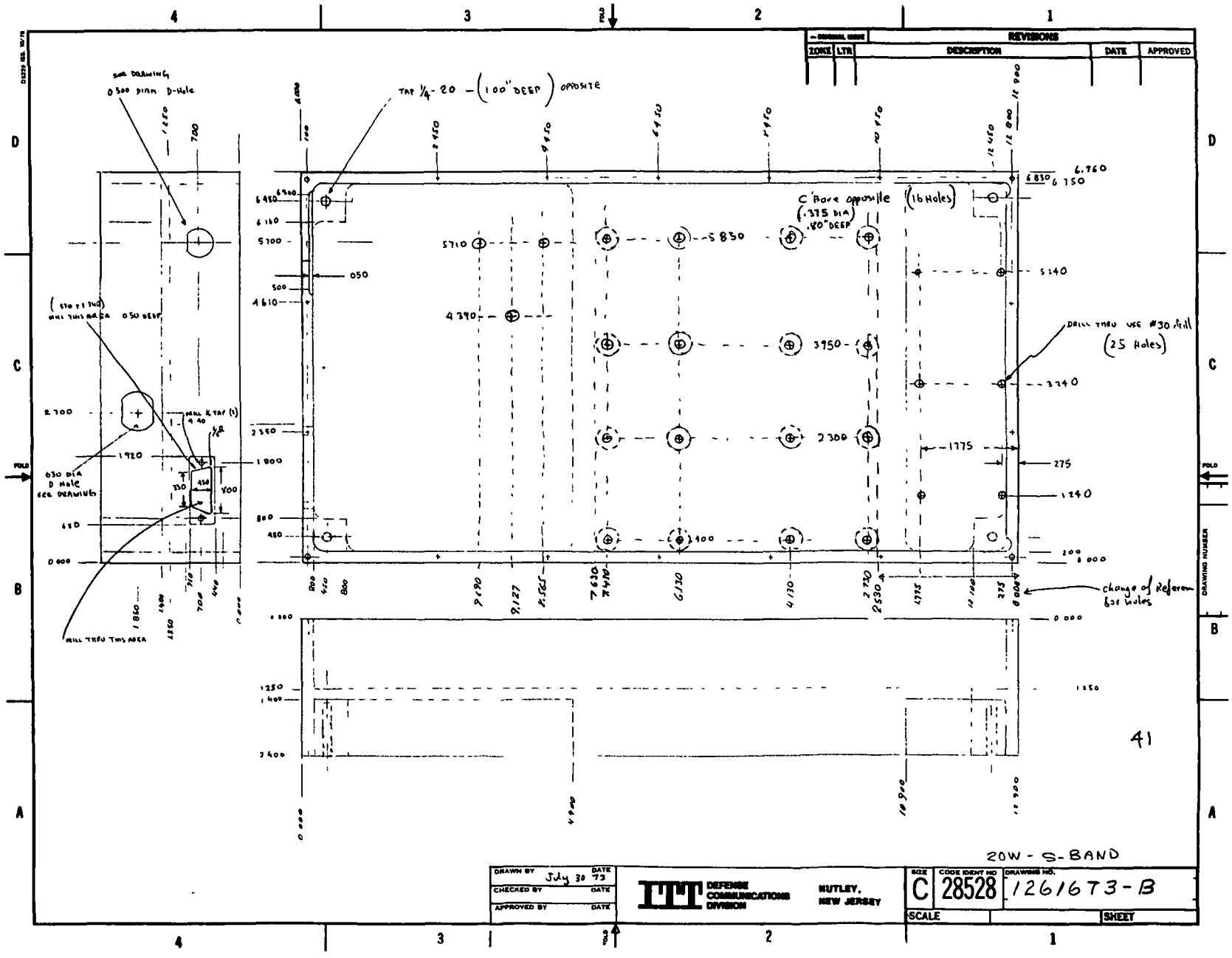
40

CHASSIS

POWER AMPLIFIER MECHANICAL LAYOUT

20-WATT S-BAND

DRAWN BY	DATE	ITT DEFENSE COMMUNICATIONS DIVISION	NUTLEY, NEW JERSEY	SIZE C	CODE IDENT NO 28528	DRAWING NO 1261659
CHECKED BY	DATE			SCALE		SHEET
APPROVED BY M. Dy	DATE 12/11/72					


REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
TAP 1/4-20 (.100" DEEP) OPPOSITE
C'Bore opposite (16 Holes)
(.375 DIA .80" DEEP)
DRILL THRU USE #30 drill (25 Holes)
change of Reference Holes
MILL THRU THIS AREA
20W - S-BAND
DRAWN BY July 30 '73
CHECKED BY
APPROVED BY
DEFENSE COMMUNICATIONS DIVISION
NUTLEY, NEW JERSEY
SIZE C
CODE IDENT NO 28528
DRAWING NO. 1261673-B
SCALE
SHEET

41

PARTS LIST

ITT DEFENSE COMMUNICATIONS DIVISION — NUTLEY, NEW JERSEY

CONTRACT NO.	DWG	CODE	DRAWING NUMBER	REV
NAS 8-28763	A SIZE	28528	PL 1261662	LTR

SEE COVER SHEET FOR LIST TITLE, REVISION AND AUTHENTICATION

20-WATT S-BAND AMPL (DRIVER AMPLIFIER)

SH 1 "C" SIZE — SHT 2/4

QUANTITY PER GROUP G5	G4	G3	G2	G1	U OF M	ITEM OR FIND NO.	CODE IDENT	SIZE	PART OR IDENTIFYING NO. OTHER THAN ITTDCD	SIZE	SPECIFICATION NO. / ITTDCD PART NO.	NOMENCLATURE OR DESCRIPTION	ITTDCD SOURCE
									MODEL 3M-6dB			ATTENUATOR, FIXED, 6DB, 2WATT	AT1
												WEINSCHEL	
									MODEL 404 AA			ATTENUATOR, VARIABLE, 1-10 dB	AT2
												1 dB STEPS KAY ELECTRIC CO.	
									A 8888			ATTENUATOR, FIXED, 3dB, SULITRON	AT3
									RC07			RESISTOR, FIXED. 150 OHMS, ± 5%	R1
									RC07			RESISTOR, FIXED 2.7 KOHMS, ± 5%	R2
									RC 32			RESISTOR FIXED. 200 OHMS, ± 5%	R3
									RC 20			RESISTOR, FIXED, 1 OHM, ± 5%	R4
									RC 20			RESISTOR, FIXED. 2.2 OHMS, ± 5%	R5
									RC 20			RESISTOR, FIXED, 27 OHMS, ± 5%	R6
									MSC 80064			TRANSISTOR, NPN, SILICON, MSC	Q1
									MSC 4000			TRANSISTOR, NPN, SILICON, MSC	Q2
	42								MSC 4003			TRANSISTOR, NPN, SILICON, MSC	Q3

U OF M | 1 PIECE 6 PAIR 32 FEET 52 U.S. FLUID OZ. 55 U.S. GAL.

* IN PART NO. COL. DENOTES VENDOR ITEM. SEE SOURCE OR SPECIFICATION CONTROL DWG.

PARTS LIST

ITT DEFENSE COMMUNICATIONS DIVISION — NUTLEY NEW JERSEY

CONTRACT NO.	DWG	CODE	DRAWING NUMBER	REV
NAS 8-28763	A SIZE	28528	PL 1261662	LTR

SEE COVER SHEET FOR LIST TITLE. REVISION AND AUTHENTICATION

20-WATT S-BAND AMPL (DRIVER AMPLIFIER)

SHT 3/4

ITTDCD D5213 (NI) V REV 1/68

QUANTITY PER GROUP G5	G4	G3	G2	G1	U OF M	ITEM OR FIND NO.	CODE IDENT	SIZE	PART OR IDENTIFYING NO. OTHER THAN ITTDCD	SIZE	SPECIFICATION NO. / ITTDCD PART NO.	NOMENCLATURE OR DESCRIPTION	ITTDCD SOURCE
									ATC 100A 510KC			CAPACITOR, FIXED, 51 pf, ±5% ATC	C1
									STYLE CKR75			CAPACITOR, FEEDTHRU, CERAMIC, 100pf	C2
												CAPACITOR, SAME AS C2	C3
									CKR06CW103M			CAPACITOR, FIXED, CERAMIC, .01µf ±20%	C4
												CAPACITOR, SAME AS C1	C5
												CAPACITOR, SAME AS C2	C6
												CAPACITOR, SAME AS C4	C7
												CAPACITOR, SAME AS C1	C8
												CAPACITOR, SAME AS C1	C9
												CAPACITOR, SAME AS C2	C10
												CAPACITOR, SAME AS C4	C11
									K3R9J50K			CAPACITOR, TANTALUM, 3.9µf ± 10%	C12
												KEMET	
												CAPACITOR, SAME AS C1	C13
									STYLE FL42			FILTER, LINE	FL1
	43												

U OF M CODE | 1 PIECE 5 SET | 6 PAIR 20 REE DOC | 32 FEET | 52 U.S. FLUID OZ. 54 U.S. LIQUID QT | 55 U.S. GAL. 68 LB AVDP

* IN PART NO. COL. DENOTES VENDOR ITEM: SEE SOURCE OR SPECIFICATION CONTROL DWG

PARTS LIST

ITT DEFENSE COMMUNICATIONS DIVISION — NUTLEY NEW JERSEY

CONTRACT NO.	DWG	CODE	DRAWING NUMBER	REV
NAS 8-28763	A SIZE	28528	PL 1261662	LTR

SEE COVER SHEET FOR LIST TITLE. REVISION AND AUTHENTICATION

20-WATT S-BAND AMPL (DRIVER AMPLIFIER)

SHT 4/4

QUANTITY PER GROUP G5	G4	G3	G2	G1	U OF M	ITEM OR FIND NO.	CODE IDENT	SIZE	PART OR IDENTIFYING NO OTHER THAN ITTDCD	SIZE	SPECIFICATION NO. / ITTDCD PART NO.	NOMENCLATURE OR DESCRIPTION	ITTDCD SOURCE
												MATCHING NETWORK, MICROSTRIP	Z1
												MATCHING " "	Z2
												MATCHING " "	Z3
												MATCHING " "	Z4
												MATCHING " "	Z5
												MATCHING " "	Z6
												MATCHING " "	Z7
												MATCHING " "	Z8
												MATCHING " "	Z9
										C	1261662	SCHEMATIC	

U OF M CODE | 1 PIECE 5 SET | 6 PAIR 20 REF DOC | 32 FEET | 52 U.S. FLUID OZ. 54 U.S. LIQUID QT. | 55 U.S. GAL. 68 LB AVDP

* IN PART NO. COL. DENOTES VENDOR ITEM: SEE SOURCE OR SPECIFICATION CONTROL DWG.

PARTS LIST

ITT DEFENSE COMMUNICATIONS DIVISION — NUTLEY, NEW JERSEY

CONTRACT NO. NAS 8-28763 | DWG SIZE A | CODE 28528 | DRAWING NUMBER PL 1261663 | REV LTR

SEE COVER SHEET FOR LIST TITLE, REVISION AND AUTHENTICATION

20-WATT S-BAND (POWER AMPLIFIER-HYBRIDS)

SH 1 "C" SIZE | SHT 2/4

QUANTITY PER GROUP G5	G4	G3	G2	G1	U OF M	ITEM OR FIND NO.	CODE IDENT	SIZE	PART OR IDENTIFYING NO OTHER THAN ITTDCD	SIZE	SPECIFICATION NO. / ITTDCD PART NO.	NOMENCLATURE OR DESCRIPTION	ITTDCD SOURCE
									ATC 100A 510 KC			CAPACITOR, FIXED, CHP. 51 µf, ± 5%, ATC	C1
												CAPACITOR, SAME AS C1	C2
									STYLE CKR75			CAPACITOR, FIXED, CERAMIC, 100 pf	C3
									CKR06CW103M			CAPACITOR, FIXED, CERAMIC, .01µf ± 20%	C4
												CAPACITOR, SAME AS C1	C5
												CAPACITOR, SAME AS C1	C6
												CAPACITOR, SAME AS C3	C7
												CAPACITOR, SAME AS C4	C8
												CAPACITOR, SAME AS C1	C9
												CAPACITOR, SAME AS C1	C10
												CAPACITOR, SAME AS C3	C11
												CAPACITOR, SAME AS C4	C12
												CAPACITOR, SAME AS C1	C13
												CAPACITOR, SAME AS C1	C14
												CAPACITOR, SAME AS C3	C15
												CAPACITOR, SAME AS C4	C16
	45								K3R9J50K			CAPACITOR, TANTALUM, 3.9 µf ± 10% KEMET	C17

U OF M CODE | 1 PIECE 5 SET | 6 PAIR 20 REF DOC | 32 FEET | 52 U.S. FLUID OZ. 54 U.S. LIQUID QT. | 55 U.S. GAL. 68 LB AVDP

* IN PART NO. COL. DENOTES VENDOR ITEM. SEE SOURCE OR SPECIFICATION CONTROL DWG.

PARTS LIST

ITT DEFENSE COMMUNICATIONS DIVISION — NUTLEY, NEW JERSEY

CONTRACT NO. NAS8-28763 | DWG SIZE A | CODE 28528 | DRAWING NUMBER PL 1261663 | REV LTR

SEE COVER SHEET FOR LIST TITLE, REVISION AND AUTHENTICATION

20-WATT S-BAND (POWER AMPLIFIER-HYBRIDS)

SHT 3/4

ITTDCD D5213 (N) V REV 1/68

QUANTITY PER GROUP G5	G4	G3	G2	G1	U OF M	ITEM OR FIND NO.	CODE IDENT	SIZE	PART OR IDENTIFYING NO. OTHER THAN ITTDCD	SIZE	SPECIFICATION NO. / ITTDCD PART NO.	NOMENCLATURE OR DESCRIPTION	ITTDCD SOURCE
									AIL P/N 3B3988			FILTER, BAND-PASS 2.2-2.3 GHz	FL1
												AIL,	
									STYLE FL42			FILTER, LINE	FL2
												COUPLER, 3 dB 90°, STRIPLINE	Z1
												COUPLER, 3 dB, 90°, STRIPLINE	Z2
												COUPLER, 3 dB, 90°, STRIPLINE	Z3
												COUPLER, 3 dB, 90°, STRIPLINE	Z4
												MATCHING NETWORKS, MICROSTRIP	Z5
												MATCHING NETWORK, MICROSTRIP	Z6
												MATCHING 1/4λ SECTION, MICROSTRIP	Z7
												MATCHING 1/4λ SECTION, MICROSTRIP	Z8
									1011 02233			ISOLATOR, 2.2-2.3 GHz, ADDINGTON	HY1
	94												

U OF M CODE | 1 PIECE 5 SET 6 PAIR 20 REF DOC 32 FEET 52 U.S. FLUID OZ. 54 U.S. LIQUID QT. 55 U.S. GAL. 68 LB AVDP

* IN PART NO. COL. DENOTES VENDOR ITEM: SEE SOURCE OR SPECIFICATION CONTROL DWG.

ITTDCD 05213 (IN) V REV 1/68

PARTS LIST

ITT DEFENSE COMMUNICATIONS DIVISION — NUTLEY, NEW JERSEY

CONTRACT NO.	DWG	CODE	DRAWING NUMBER	REV
NAS 8-28763	A SIZE	28528	PL 1261663	LTR

SEE COVER SHEET FOR LIST TITLE, REVISION AND AUTHENTICATION

20-WATT S-BAND (POWER AMPLIFIER HYBRIDS)

SHT 4/4

QUANTITY PER GROUP G5	G4	G3	G2	G1	U OF M	ITEM OR FIND NO.	CODE IDENT	SIZE	PART OR IDENTIFYING NO. OTHER THAN ITTDCD	SIZE	SPECIFICATION NO. / ITTDCD PART NO.	NOMENCLATURE OR DESCRIPTION	ITTDCD SOURCE
									SERIES 7696			RESISTOR, FIXED, STUD, 50 OHMS, 20 WATT	R1
												SOLITRON DEVICES, INC.	
												RESISTOR, SAME AS R1	R2
												RESISTOR, SAME AS R1	R3
												RESISTOR, SAME AS R1	R4
												RESISTOR SAME AS R1	R5
												RESISTOR, SAME AS R1	R6
									RC 20			RESISTOR FIXED, 1 OHM, ± 5%	R7
												RESISTOR, SAME AS R7	R8
												RESISTOR, SAME AS R7	R9
												RESISTOR, SAME AS R7	R10
									RC 20			RESISTOR, FIXED, 2.7 OHMS, ± 5%	R11
									MSC-4005			TRANSISTOR, NPN, SILICON, MSC	Q1
												TRANSISTOR, SAME AS Q1	Q2
												TRANSISTOR, SAME AS Q1	Q3
	47											TRANSISTOR, SAME AS Q1	Q4
										C	1261663	SCHEMATIC	

U OF M CODE | 1 PIECE 5 SET | 6 PAIR 20 REF DOC | 32 FEET | 52 U.S. FLUID OZ. 54 U.S. LIQUID QT. | 55 U.S. GAL. 68 LB AVDP

* IN PART NO. COL. DENOTES VENDOR ITEM: SEE SOURCE OR SPECIFICATION CONTROL DWG.