ADVANCED ANTENNAS

C-BAND 500 MHz DUPLEXER

Report No. RML-009-85-71

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Report No. RML-009-85-71

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Technical Report Abstract	Spar Aerospace Limited Ste-Anne-de-Bellevue	Company Private

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Abstract - Briefly summarize objectives, methods, results, & applications - Type single spaced.

A design of a duplexer using non-uniform shunt stubs as resonators is presented in this report. The design procedure uses lumped element, low-pass prototype filters realized in TEM transmission line medium. The resulting duplexer is very compact, having relatively non critical manufacturing tolerances and a high stop-band attenuation which is necessary to isolate transmit and receive frequency bands. The duplexer has been developed without inclusion of any tuning screws.

The theoretical performance of the duplexer and the measured results show good agreement.

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1.0 INTRODUCTION

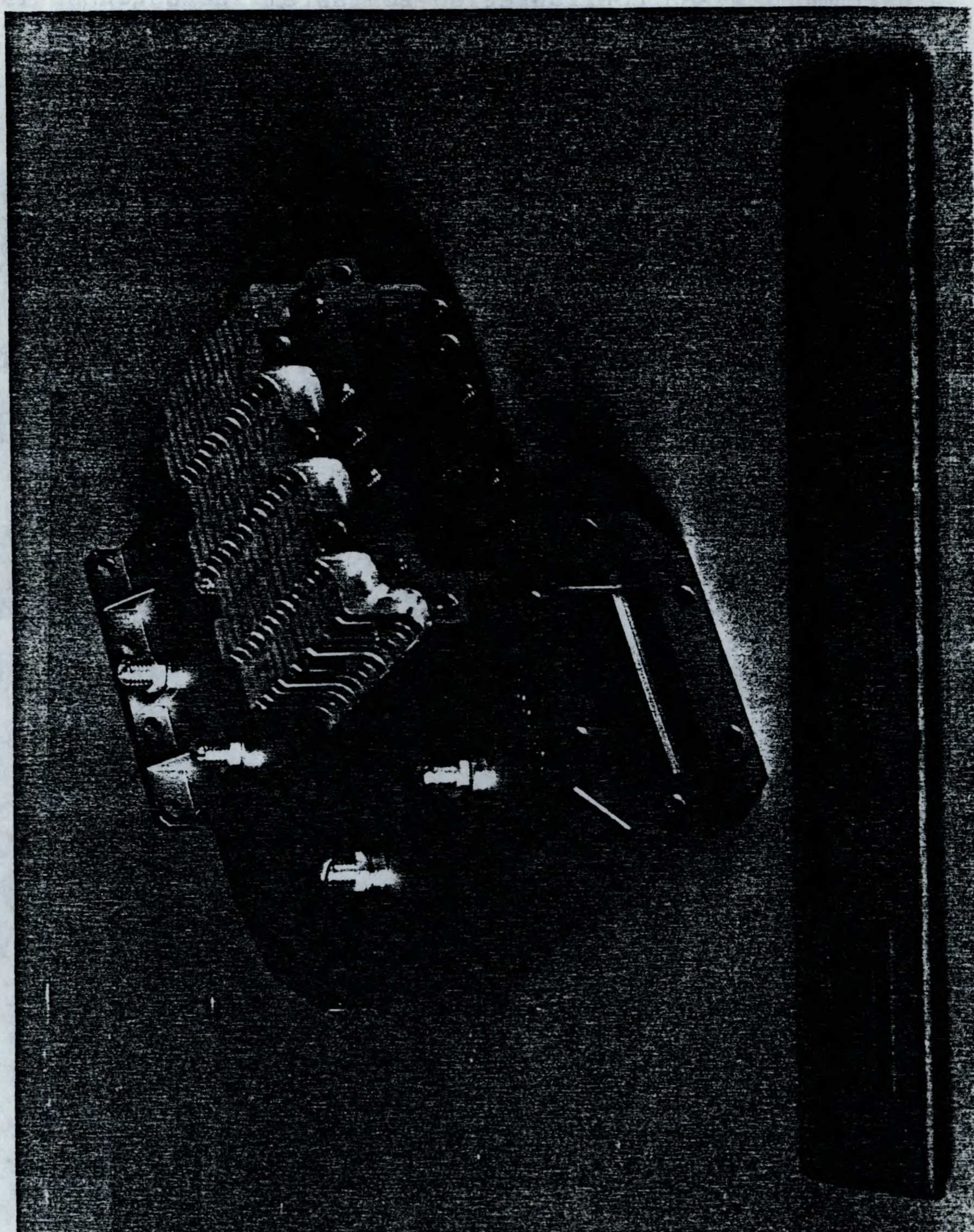
A commonly used configuration for satellite antennas is one where the feed horns and the reflector are shared by both the transmit and the receive signals. In such a situation a duplexer is required to separate out the two signals.

Figure 1.1 shows the current design of the duplexer as used on BRASILSAT. The design is in waveguide. The TX filter is realized as a series of alternating large and small aperture plates, while the RX filter is essentially a section of waveguide that is below cut-off to the TX frequency band. As a waveguide design, it is relatively compact, and of course it is low-loss, of the order of 0.1 dB in each band.

Antenna technology is progressing and at C-band there is the trend towards greater use of the TEM-line medium in other parts of the feed, other than the coupler networks, as was the case in BRASILSAT. A design in TEM-line or one that is compatible with TEM-line is therefore required in a component such as the duplexer. The waveguide design described above is not compatible.

This report commences with a survey of possible candidates, followed by the recommendation of the preferred approach, then by a description of the theory, breadboard and measured results of the selected design.

FIG 1.1 BRASILSAT DUPLEXER IN WAVEGUIDE



2.0 FILTER SELECTION

The main criteria in selecting the optimum filter candidate are firstly that the design is amenable to fabrication as part of an integrated assembly. Second, because of the integrated nature, it is equally important that the design requires minimum or no tuning, ie. the design must be rather insensitive to dimensional tolerances. Third, it must be realizable either in the TEM-line medium or in a medium that is compatible to TEM. The latter implies ease of interfacing and also similar size. Fourth, the design should be relatively small and low-loss.

A number of filter candidates could be considered to be realizable either in the TEM-line medium or in a medium that is compatible to TEM. These candidates are:

a) evanescent mode filter
b) interdigital filter
c) combline filter
d) coupled half-wave lines
e) quarter-wave or half-wave stub filter.

The first three, which find wide application, may be considered quasi-TEM and they can be designed to interface with TEM-line. They are however rather sensitive and they require extensive tuning on an individual basis. They are therefore not very suitable and are eliminated from the selection.

Item (d), which is shown in Figure 2.1 is a TEM-line design. It is realizable either as open-circuited half wave lines or as short-circuited half-wave lines. Mechanically the short-circuit configuration is preferred because of its self-supporting nature, and also each short circuit serves as a heat conduction path. Electrically however, the short circuit can be problematic and care must be taken to ensure a good short. The design is compact and simple. However it is somewhat sensitive particularly in the coupling between lines and some adjustment is anticipated.

Filters classified under item (e) are readily implemented in TEM-line. A number of configurations are possible, These are shown in Figure 2.2. Figure 2.2. (a) shows a design, using series connected open circuit quarter wave lines. Each quarter-wave stub is realized within a quarter-wave connecting line, resulting in a very compact tubular design. However, this comes with a penalty; the quarter wave stub tends to be very thin, 0.010 to 0.030 inch in diameter for the application here. The small size, the dielectric sleeves, and the many piece parts make the design unattractive besides being sensitive.

Figure 2.2 (b) is the electrical dual of 2.2 (a) in that the quarter wave stubs are short circuited and connected in shunt to the main line. This design is larger, but it is much more amenable to fabrication and handling, and is not sensitive. No tuning is expected. The stubs are easily machined integral with the main line. Further, tolerances are easily maintained and the unit lends itself to easy inspection. One drawback however, is the need for a short circuit for each stub. But this short circuit can be avoided by using half-wave stubs as shown in Figure 2.2 (c). Replacing the quarter-wave lines by half-wave lines results in approximately 25% increase in area, but the design is still relatively small. An additional benefit with half-wave stubs is the increased flexibility in the design in that stub impedance level (hence stub size) can be changed by 'stepping', ie having the stub realized as two quarter wave stubs of different impedances, as shown in Figure 2.2 (d). This flexibility is useful because the realizable impedance range is not large. This limited range is often a design constraint. "Stepping" also permits relocation of attenuation poles and this can be applied to increase stop-band attenuation in a specific region.

Based upon the foregoing, the recommendation is the filter with open-circuit half-wave stubs, with "stepping" if required.

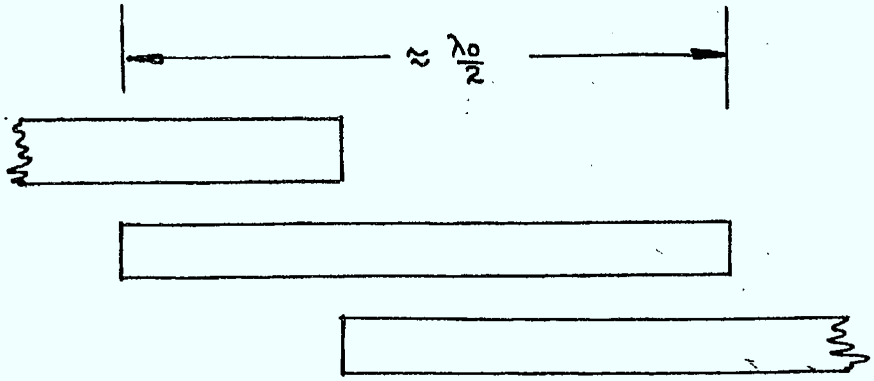


Fig 2.1 (a) PARALLEL-COUPLED FILTER
(OPEN CIRCUIT RESONATOR)

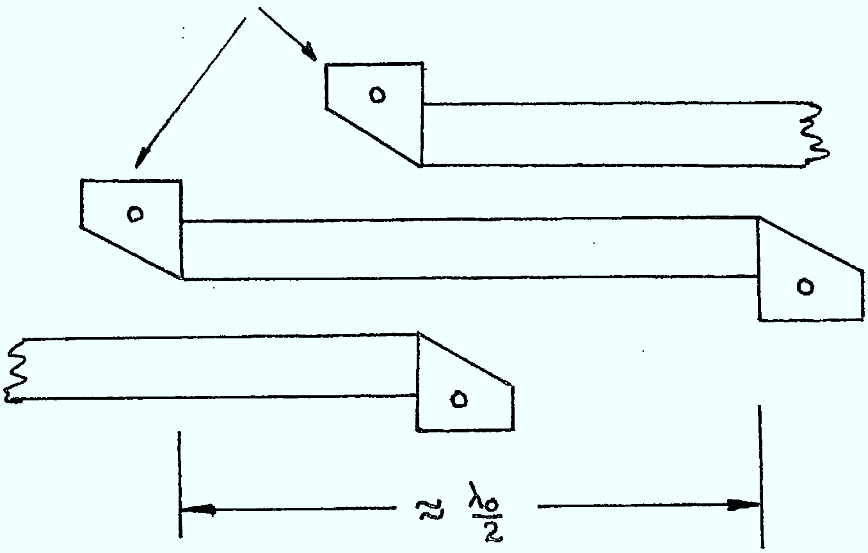


Fig 2.1 (b) PARALLEL-COUPLED FILTER
(SHORT CIRCUIT RESONATOR)

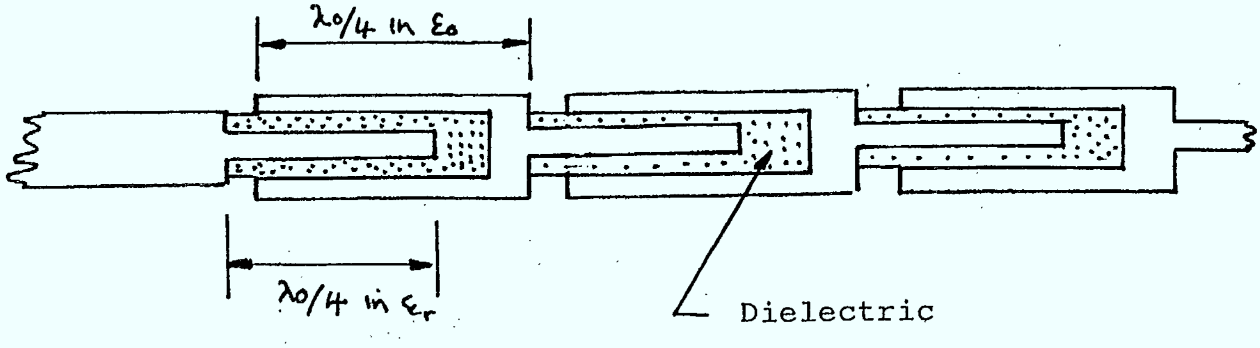


Fig 2.2 (a) SERIES STUBS

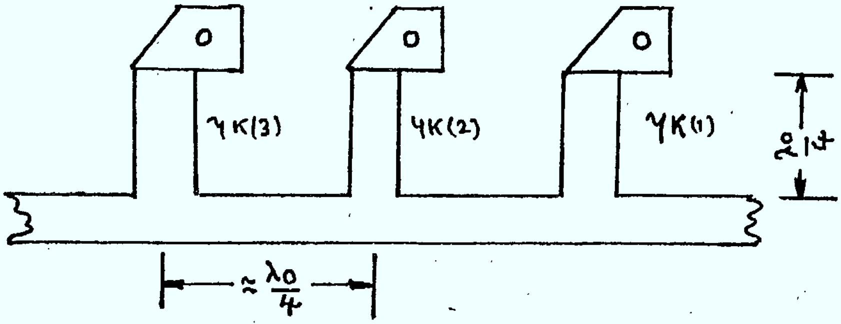


Fig 2.2 (b) ¼ WAVE SHORT-CIRCUIT STUBS

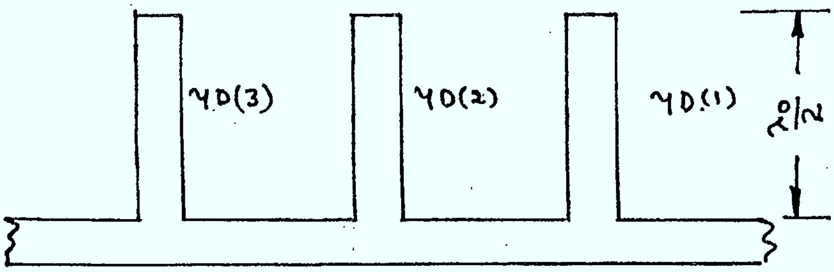


Fig 2.2 (c) ½ WAVE OPEN CIRCUIT STUBS

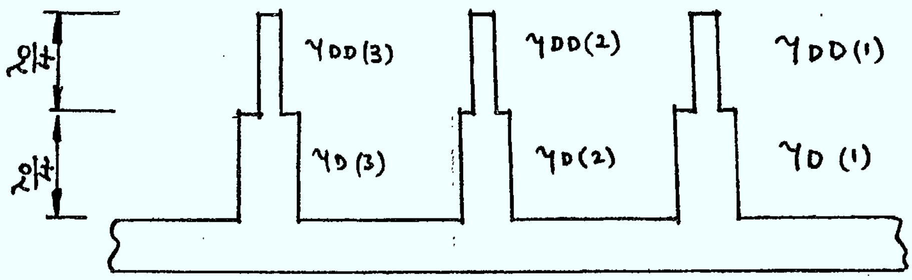


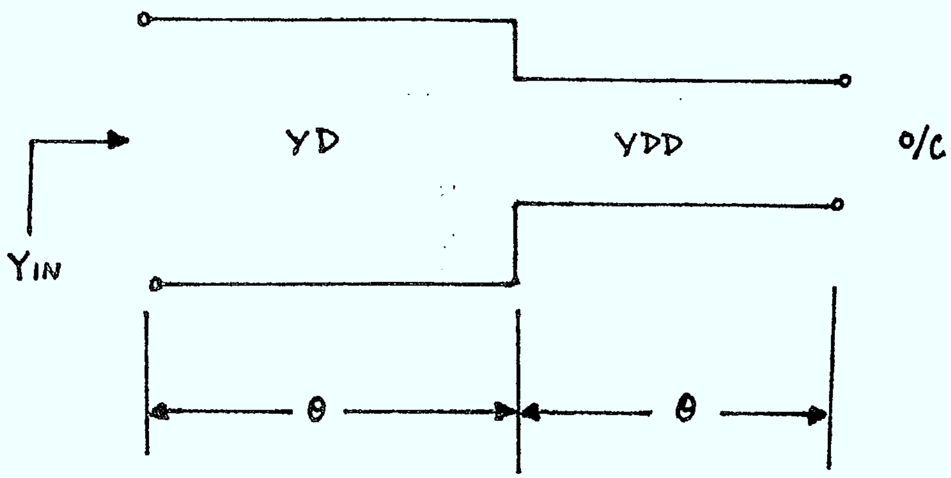
Fig 2.2 (d) ½ WAVE OPEN CIRCUIT STEPPED STUBS

3.0 Theory

A method of design of duplexer combines the image and the insertion loss point of view to give approximate design method having simplicity and also precision.

The desired insertion loss characteristic is obtained by use of the lumped-element Chebyshev low-pass prototype. With the aid of the concept of impedance inverters, the prototype is converted to a cascade of symmetrical but differing sections. The image properties of the symmetrical sections are then related to corresponding sections of the prototype. The design equations has already been derived (Ref. 4) for a band-pass filter with quarter-wavelength shunt stubs and quarter-wavelength connecting lines.

The filter of the form in Fig. (2.2b) can be readily designed by modified use of the equations in Ref. (4). In this case, each shunt quarter-wavelength short-circuited stub of characteristic admittance YK is replaced by a shunt, half-wavelength open circuited stub (Fig. 2.2d) with modification to the characteristic admittance YD. (YK=2YD). Consider a case of non-uniform shunt open-circuited stub as shown in the figure below.



The ABCD matrix of each portion can be written as

$$\begin{bmatrix} \cos\theta & \frac{j}{y_D}\sin\theta \\ j y_D \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} \cos\theta & \frac{j}{y_{DD}}\sin\theta \\ j y_{DD} \sin\theta & \cos\theta \end{bmatrix}$$

The resulting matrix is

$$= \begin{bmatrix} c^2 - \frac{y_{DD}}{y_D} s^2, & \frac{j}{y_{DD}} s.c + \frac{j}{y_D} s.c., \\ j\gamma_D s.c. + j\gamma_{DD} c.s, & c^2 - \frac{y_D}{y_{DD}} s^2 \end{bmatrix}$$

where
$c = \cos\theta$
$s = \sin\theta$

$$= \begin{bmatrix} A & jB \\ jC & D \end{bmatrix} \quad \text{Say}$$

This stub when connected to terminating resistance of unity as shown in Fig. 4.1 gives

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & jB \\ jC & D \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix}$$

$$\therefore \quad \begin{aligned} E_1 &= A E_2 \\ I_1 &= jC\, E_2 \end{aligned} \qquad \text{since } I_2 = 0 \quad o/c$$

Then input admittance Y_{in} , is given by

$$Y_{in} = \frac{I_1}{E_1} = \frac{jC}{A} = \frac{j \sin\theta \cos\theta \,(Y_D + Y_{DD})}{\cos^2\theta - \frac{Y_{DD}}{Y_D} \sin^2\theta}$$

$$Y_{in} = \frac{j\,(Y_{DD} + Y_D)}{\cot\theta - \frac{Y_{DD}}{Y_D} \tan\theta} \qquad -(2)$$

Now, constraints are made to yield half-wavelength o/c shunt stubs to have exactly same suceptance at band edge frequency W_1, as did the quarter-wave stubs that they replace with both kinds of stubs to have zero-admittance at Wo

i.e. $\theta = \frac{\pi}{2}, \; Y_{in} = 0$

and $Y_{in} = \infty$ at ω_∞ in eqn(2)

i.e. $\cot \theta_\infty = \frac{Y_{DD}}{Y_D} \tan \theta_\infty$

$$\cot^2 \theta_\infty = \frac{Y_{DD}}{Y_D} = a$$

and we want $Y_{in\,1} = Y_{in\,2}$ at ω_1

$Y_{in\,1} = -jY_o \cot \theta$ i.e. $\lambda/4$ s/c shunt stub

$$\therefore \quad -jY_o \cot \theta_1 = \frac{j(Y_D + Y_{DD})}{\cot \theta_1 - \frac{Y_{DD}}{Y_D} \tan \theta_1}$$

$$Y_D = \frac{Y_o (a \tan^2 \theta - 1)}{(a+1) \tan^2 \theta} \qquad -(3)$$

The advantage of this transformation can be now seen. For uniform impedance stub, stop-band will have infinite attenuation at $\omega_0/2$ and $3\omega_0/2$. But if stub is stepped, the frequencies of infinite attenuation (transmission pole) are made to occur at frequencies other than $\omega_0/2$ and $3\omega_0/2$. Thus by proper choice of Y_D/Y_{DD}, ω_∞ can be made to occur to give maximum effectiveness in the stop-band. Thus by staggering ω_∞ of the stubs, a broader high attenuation band is achieved.

A computer program has been written to synthesize and analyze such structure. Prototype elements for receive-transmit filters can be optimized. The optimization aims at maximizing attenuation level and maintaining impedance level in the range 26Ω to 100Ω to obtain reasonable stub dimensions.

4.0 Computer Programs

A computer program has been written to analyze the filters. This program computes transmission loss and return loss for any order of filter. The analysis is based on the ABCD matrix, that is, each element (assumed lossless) in network is represented by ABCD matrix of form

$$\begin{bmatrix} A & jB \\ jC & D \end{bmatrix} \quad \text{where } A, B, C, D \text{ are real}$$

A cascade of the individual matrices results in combined ABCD matrix of the whole network, again of the above form.

This circuit is connected to terminating resistances of unity, Fig. 4.1 . It can be readily shown that the return loss and the transmission loss are related to the matrix elements by

$$\text{Return loss} = -10 \log_{10} \frac{(A-D)^2 + (B-C)^2}{(A+D)^2 + (B+C)^2} \quad (dB)$$

$$\text{and Transmission loss} = 10 \log_{10} \frac{(A+D)^2 + (B+C)^2}{4} \quad (dB)$$

These parameters are computed by the program. The synthesis of the filters is followed by analysis of the integral duplexer, again using ABCD matrix analysis. Referring to Fig. (4.2), if the transmission line connecting the filter is transformed and then absorbed in the net ABCD matrix, then input admittance is given by

$$Y_{IN}(T) = \frac{D' + jC'}{A' + jB'} \qquad Y_{in}(R) = \frac{D'' + jC''}{A'' + jB''}$$

then $$Y_{IN} = Y_{in}(T) + Y_{in}(R)$$

and the reflection coefficient is

$$\Gamma = \frac{Y_{in} - 1}{Y_{in} + 1}$$

Return loss = 20 $\text{Log}_{10} |\Gamma|$ (dB).

The computer program written enables manual optimization of the duplexer return loss by changing connecting line lengths and their characteristic admittances.

The analysis program for the duplexer can be run directly or via an input data file and the results of duplexer return loss printed out as shown in the computer run. A complete listing and example runs are included in the appendix.

Program 'SSS1' analyzes a single stepped stub. It assumes an ideal stub (lossless) and computes return loss, transmission loss and phase slope. This program is used to generate results that are then compared with measured values in order that correct stubs are realized.

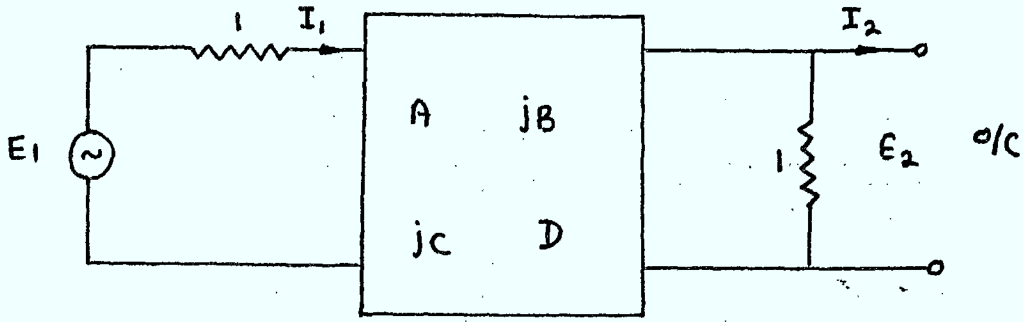


Figure 4.1 ABCD matrix representation of 2 port network

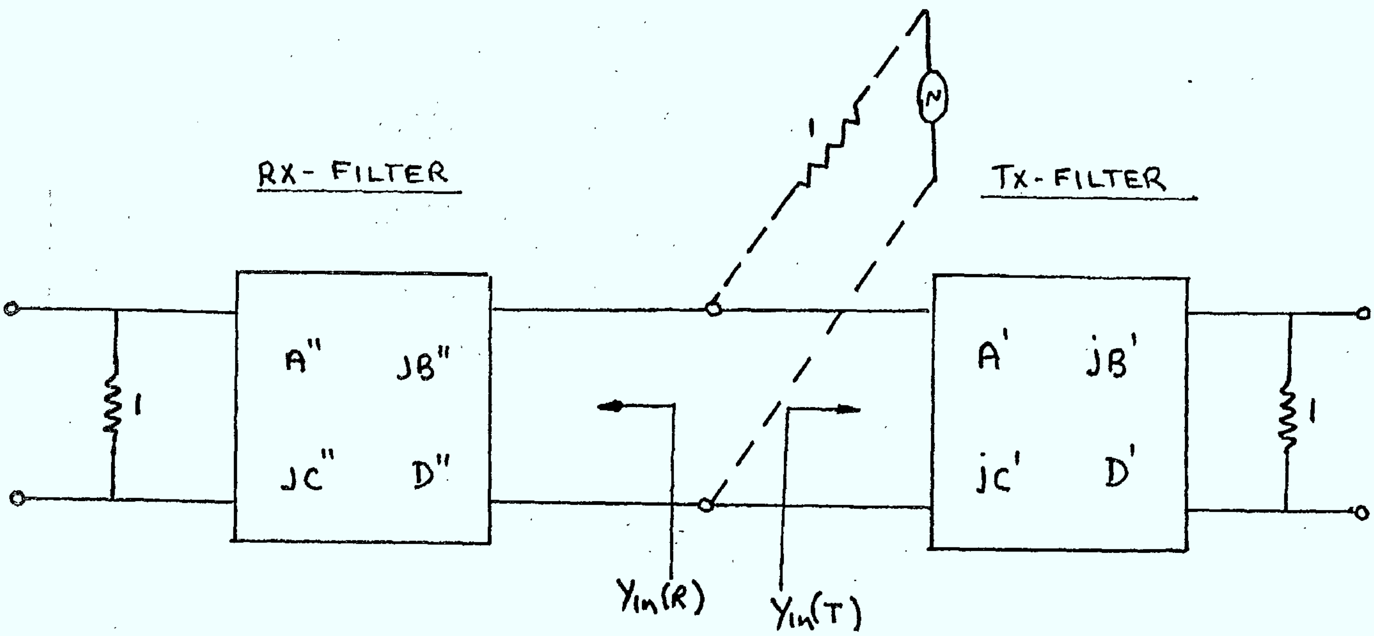


Figure 4.2 Equivalent circuit of the duplexer

5.0 Design of Duplexer

The prototype duplexer was designed using a computer program "CBDTEM". The prototype elements were optimized to give realizable stub impedance and at the same time meet the required design specifications. The computed values of the final prototype filter elements are given in Fig. 5.1.

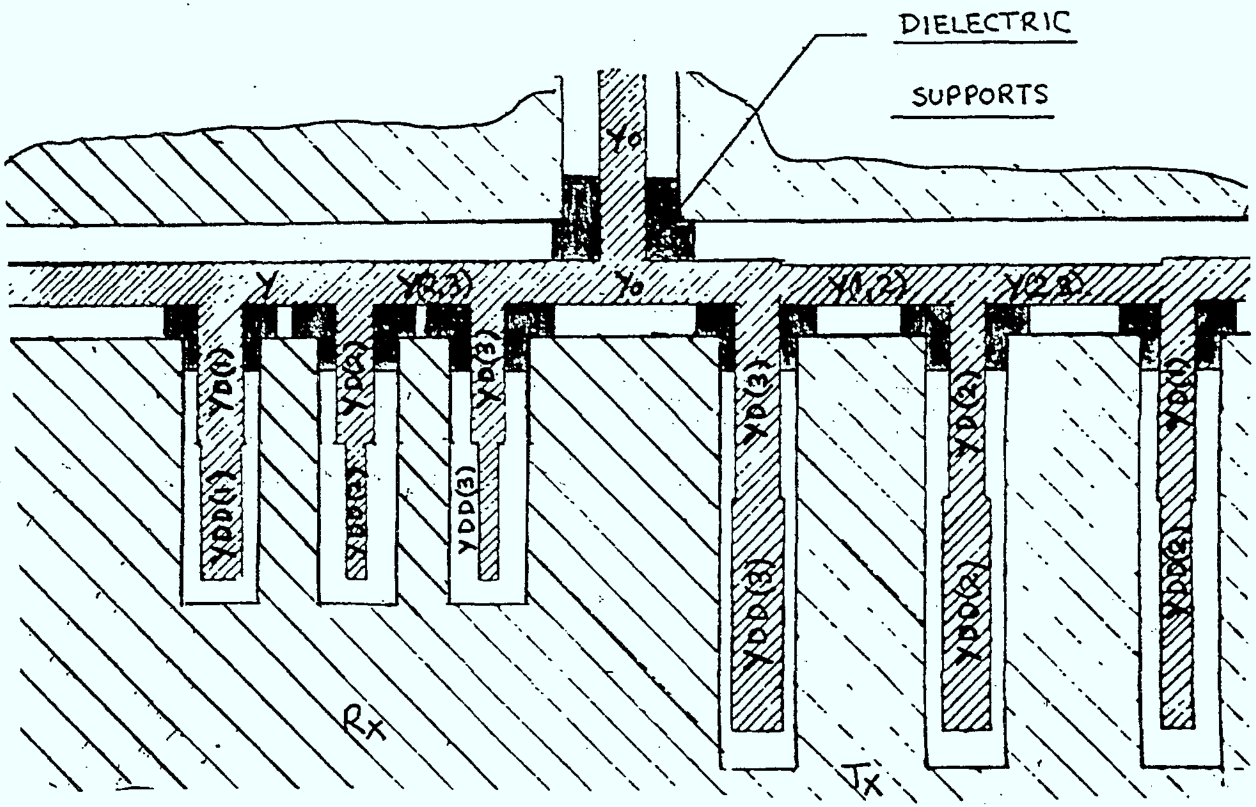
From the computed realizable prototype stub impedances, a series of stubs were manufactured to provide the range of impedances required. These stubs were measured at transmit and receive frequencies and the impedance of each was calculated from the phase slope in the vicinity of stub mid-band resonance. The stubs were supported at the "T" junction by Teflon dielectric pieces. These were designed so as to give a transformer ratio close to unity. The measured results of the stub impedance for different width (W) and thickness (t) are presented graphically in Fig. 5.2 and Fig. 5.3.

Using the measured data, proto-type uniform stubs were manufactured and then transformed to stepped stubs. It can be seen from the inspection of equation (3) that the length of the first portion of the stub determines the mid-band frequency (fo), while the admittance ratio η_D/η_{DD} determines the position of the infinite attenuation pole. The length of each stub and the impedance ratios were adjusted empirically until poles and zeros were placed according to the computed proto-type design requirements. To ensure that correct stubs were derived, phase slope was computed for each prototype stub using computer program "SSS1" and was compared with the measured phase slope of actual stub.

Table 5.1 includes the final derivation of the stepped stubs and the transformer ratio used in this design. Initially stubs were manufactured assuming the transformer ratio ($\sqrt{A}$) to be same for each portion of the stub. The actual dimensions based on this are included in Table 5.2. However, in the final realization, discontinuity of the stub altered the pole-zero positions. These were eventually adjusted for, by changing the dimensions of the stubs.

Finally, complete receive and transmit filters were manufactured and tested individually and then connected together to form a duplexer. The T-junction used for connecting the two filters was again dielectrically loaded to achieve close to unity transformer ratio.

COMPUTED - PROTO-TYPE DUPLEXER



RECEIVE FILTER

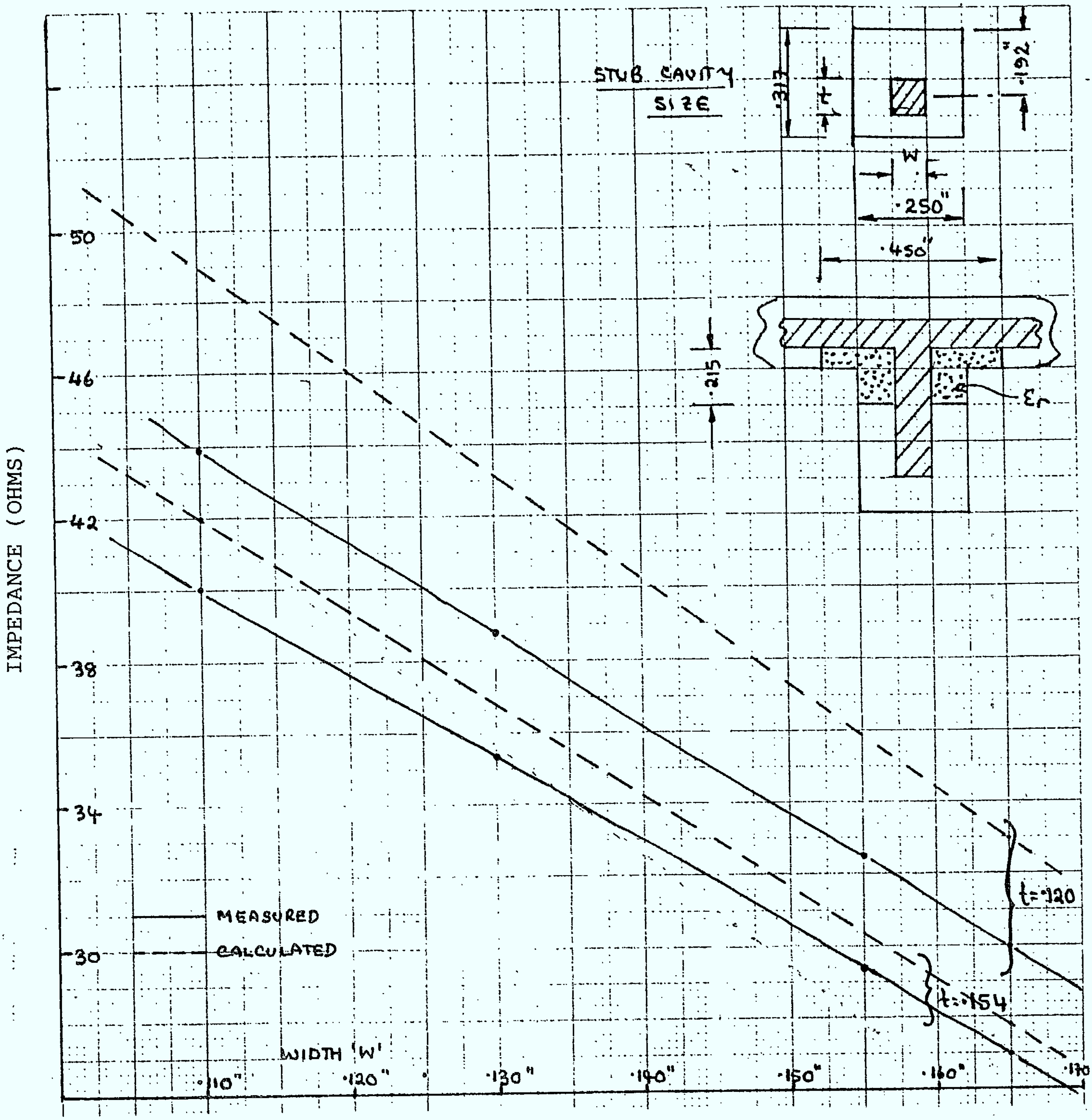
YD (1) = 1.4241 YDD(1) = .7758
YD (2) = 1.7165 YDD(2) = .5501
YD (3) = 1.2203 YDD(3) = .5209
Y(2,3) = Y(1,2) = 1.080

TRANSMIT FILTER

YD (1) = 1.2335 YDD(1) = .9068
YD (2) = 1.1391 YDD(2) = 1.6749
YD (3) = 1.5322 YDD(3) = 1.6543
Y(1,2) = Y(2,3) = .7468

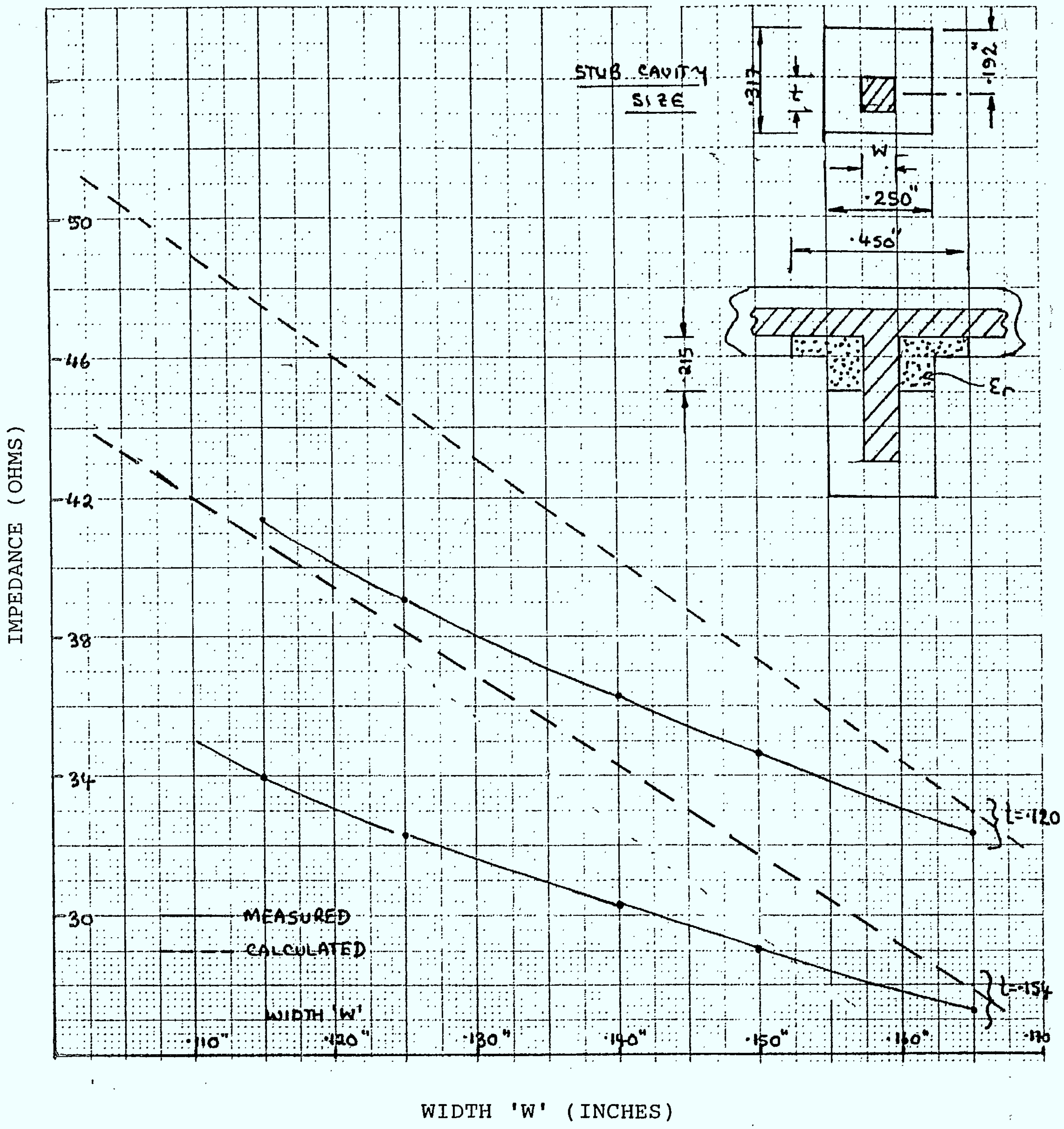
FIGURE 5.1

Fig 5.2 IMPEDANCE CHART AT TRANSMIT-FREQUENCY BAND

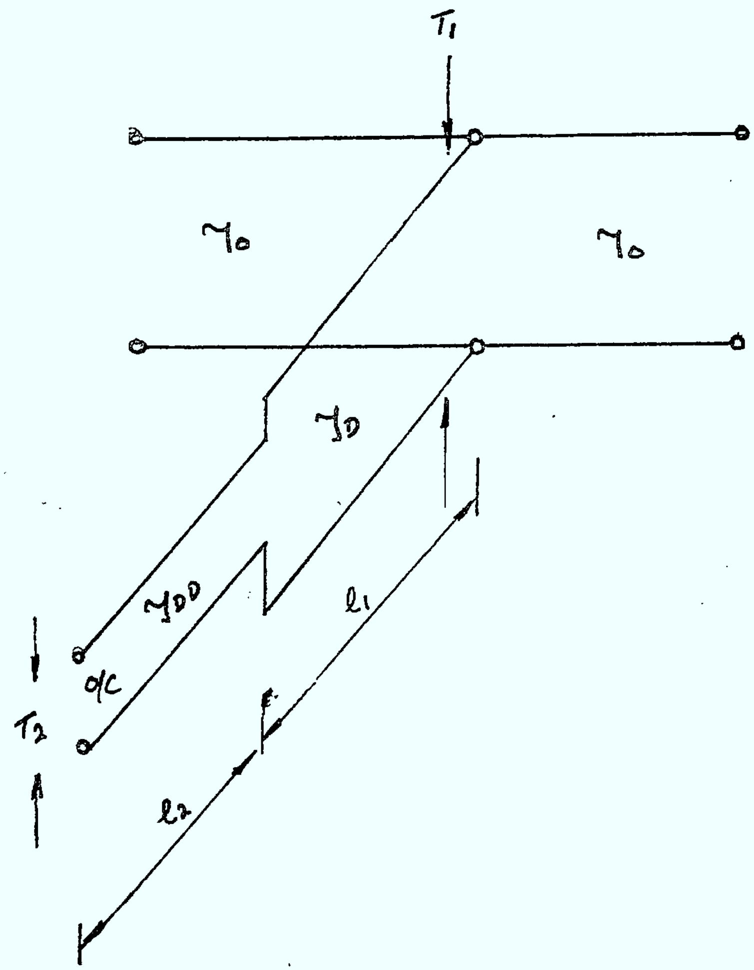


WIDTH 'W' (INCHES)

Fig 5.3 IMPEDANCE CHART AT RECEIVE-FREQUENCY BAND

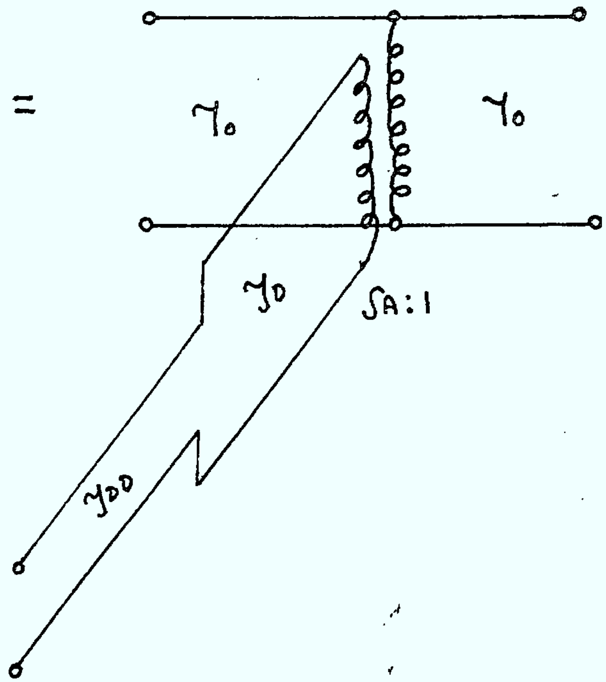


DEFINITION OF STUB-DIMENSIONS USED IN TABLE 5.1



STEP-STUB CONFIGURATION

=



EQUIVALENT CIRCUIT OF STUB

TABLE 5.1 FINAL DERIVATION OF DUPLEXER

STUBS	PROTOTYPE IMPEDANCE REQUIRED		T-JUNCTION TRANSFORMER RATIO: $\sqrt{A}$	DIMENSION OF STUBS USING DESIGN CHART FIG (5.3, 5.4) AND TRANSFORMER RATIO: $\sqrt{A}$		FINAL DIMENSION OF THE STUBS	
	ZD (Ω)	ZDD (Ω)		W1xT1xL1 (INCHES)	W2xT2xL2 (INCHES)	W1xT1xL1 (INCHES)	W2xT2xL2 (INCHES)
RECEIVE FILTER							
1	35.11	66.16	1.051	.154 x .110 x .427	.077 x .077 x .427	.154 x .110 x .411	*.065 x .065 x .443
2	29.13	90.89	1.047	.154 x .139 x .427	.047 x .047 x .427	.154 x .139 x .415	*.039 x .039 x .439
3	40.97	95.99	1.07	.120 x .115 x .427	.045 x .045 x .427	.120 x .115 x .413	*.041 x .041 x .441
TRANSMIT FILTER							
1	32.63	30.22	1.058	.120 x .154 x .667	.120 x .170 x .667	*.120 x .132 x .668	.120 x .170 x .667
2	43.89	29.85	1.055	.120 x .110 x .667	.120 x .169 x .667	*.120 x .093 x .684	.120 x .169 x .651
3	40.54	55.14	1.05	.120 x .124 x .667	.120 x .090 x .667	.120 x .124 x .645	*.120 x .104 x .690

* In final design these dimensions were changed to locate pole-zero exactly

The separations of the transmit and the receive filters relative to common port were optimized using the computer program 'CBDTEM'. However final adjustments had to be made on the test bench to obtain good results.

5.1 Dielectrical-Loaded T-Junction

A symmetrical TEM-line T-junction of the type shown in Fig. 5.4 can be represented by an equivalent circuit shown.

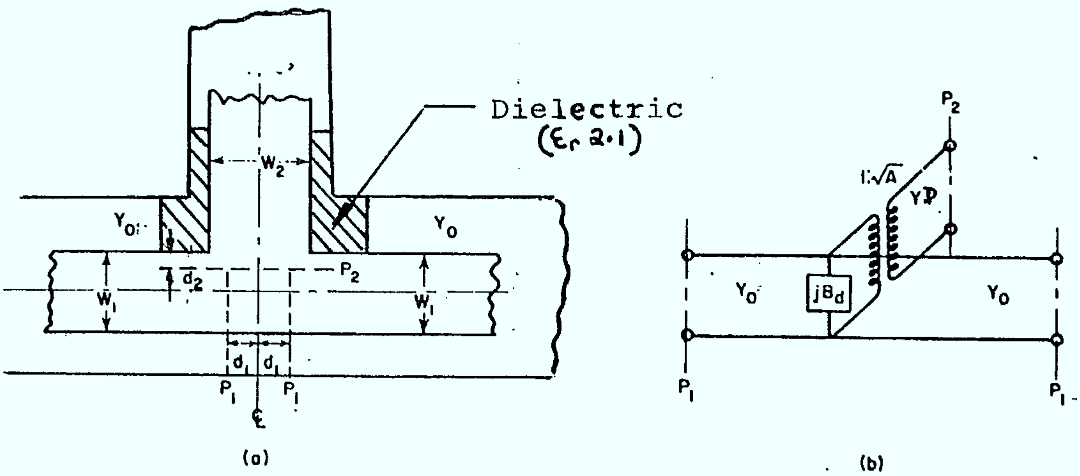


Figure 5.4

In practice, the T-junction introduces a number of effects which will alter the dimensions of the shunt stub. In relation to the equivalent circuit;

(1) The transformer ratio $\sqrt{A}$, will increase the stub impedance by a factor of 'A'. However by loading the junction with suitable dielectric, near unity transformer ratio can be achieved.

(2) The reference plane off-set d_2 which has an effect of decreasing the length of the stub by d_2, is further increased by length of the dielectric supporting the stub. In this design, resultant d_2 was found to be .103" giving stub length L= $\lambda_0/2$ - 0.103" (including the end-effects). It was found almost independent of width of the stub dimensions and frequency used for this design.

(3) The reference plane offset d_1 will increase the spacing between two stubs by $2d_1$. However in this design this is compensated by length of the dielectric in that plane. This is evident from near zero phase offset at midband frequency measured for the stubs.

6.0 Breadboard Design and Results

Initially, development filters were made of piece parts to allow for optimization on the bench. This was then followed by fabrication of integral filters. In this case central conductor and the stubs were fabricated in one piece using Electric Discharge Machine (EDM) to achieve the desired accuracy. The results of the two models are summarized in Table 5.2. From the results it can be seen that there is very good agreement between each of the units and the computed values confirming that the design is not sensitive. However the receive filter isolation in stop-band was not as much as computed. This was mainly due to large admittance ratio (y_D/y_{PD}) required to achieve correct pole-zero location thus reducing the effective attenuation in the stop-band. Results for the integral filters (in-band return loss and out-of-band isolation are shown in Table 5.2 and Figure 6.1 to 6.4. The measured return loss for both filters was 25 dB.

Finally an integral duplexer (Fig. 6.5) was fabricated as verification model. The measured results of the duplexer are summarized in Table 6.1 and the detailed results are shown in Fig. 6.6 to 6.10. The return loss measured was better than computed. From this it can be inferred that the computer model had not been fully optimized. Very good results were obtained on the bench by fine adjustment of dielectric loaded T-junction and the characteristic impedance of the transmission line connecting the filters. The isolation in the stop-band was improved by 6 dB. This is a known phenomenon and results from input admittance of the other filter being in parallel with that of reference filter. In general very good agreement between each unit has been achieved. The attractive feature of this design is that it does not require any tuning screws. The design of the duplexer is detailed in Spar drawing numbers 2549240/43, 2523197/204 and 2614559.

TABLE 5.2 COMPARISON OF COMPUTED AND MEASURED RESULTS OF FILTERS

PARAMETER	TX-FILTER DESIGN TARGET	TX-FILTER COMPUTED	TX-FILTER MEASURED DEVELOPMENT FILTER	TX-FILTER MEASURED INTEGRAL FILTER	RX-FILTER DESIGN TARGET	RX-FILTER COMPUTED	RX-FILTER MEASURED DEVELOPMENT FILTER	RX-FILTER MEASURED INTEGRAL FILTER
Return Loss (dB) 3700 to 4200 (MHz)	25	28	26	27				
5925 to 6425 (MHz)					25	26	25	26
Isolation (dB) IN STOP-BAND 5925-6425(MHz)	40	52	40	40				
3700-4200(MHz)					40	63	34	35

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TABLE 6.1 SUMMARY OF MEASURED RESULTS, DUPLEXER VERIFICATION MODEL

PARAMETER	COMPUTED VALUES		MEASURED VALUES	
	TRANSMIT PORT	RECEIVE PORT	TRANSMIT PORT	RECEIVE PORT
IN BAND (MHz)	3700-4200	5925-6425	3700-4200	5925-6425
INSERTION LOSS (dB)	0.00	.01	.115	.213
ISOLATION (dB) 5925-6425 (Min.)	58		46.65	
3700-4200 (MHz)		68		40.29
RETURN LOSS (dB)	22.85	20.1	25	25
GAIN SLOPE dB/MHz	-	-	.001	.001

TRANSMIT FILTER RESULTS

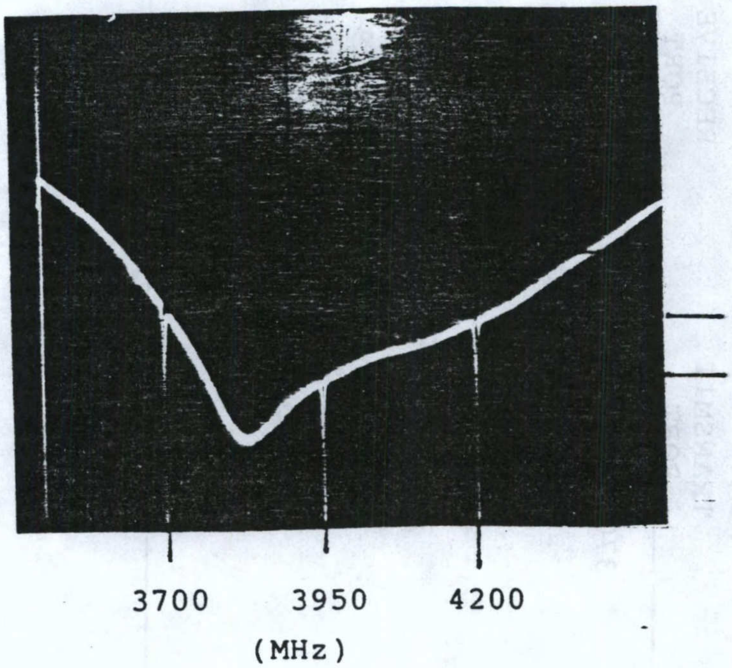


FIG 6.1 RETURN LOSS INBAND

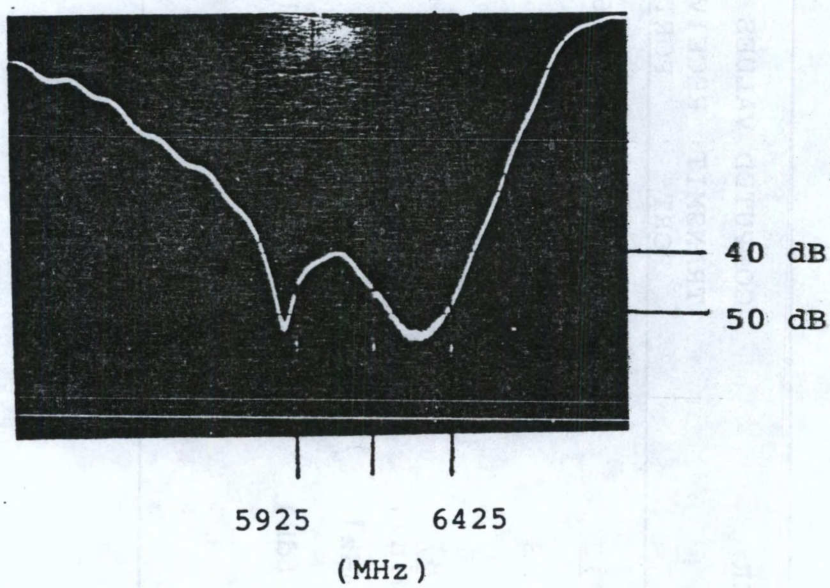


FIG 6.2 ISOLATION IN RECEIVE-BAND

RECEIVE-FILTER RESULTS

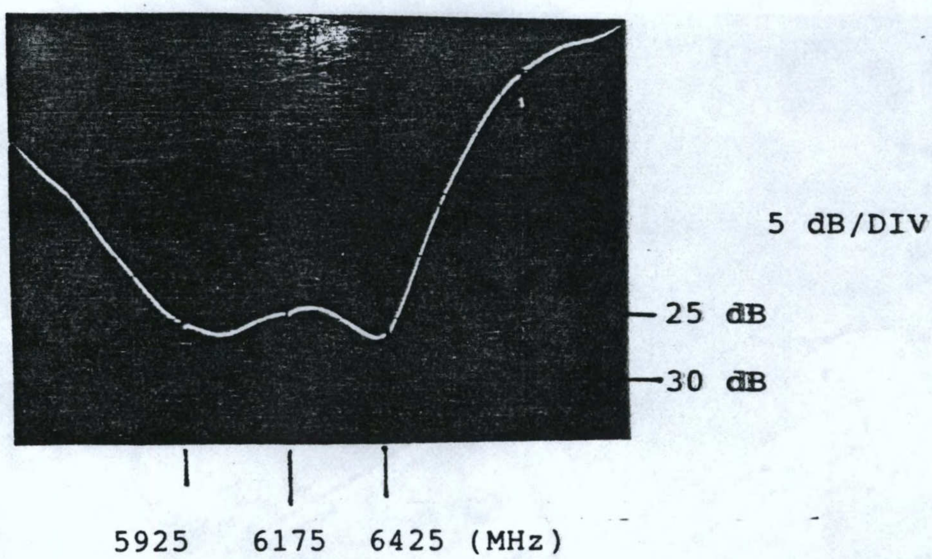


FIG 6.3 RETURN-LOSS INBAND

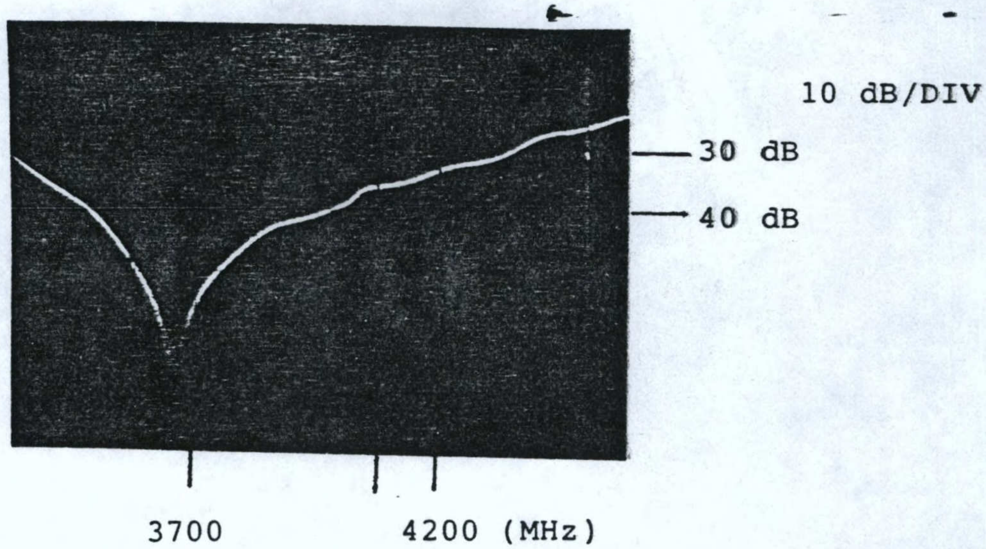
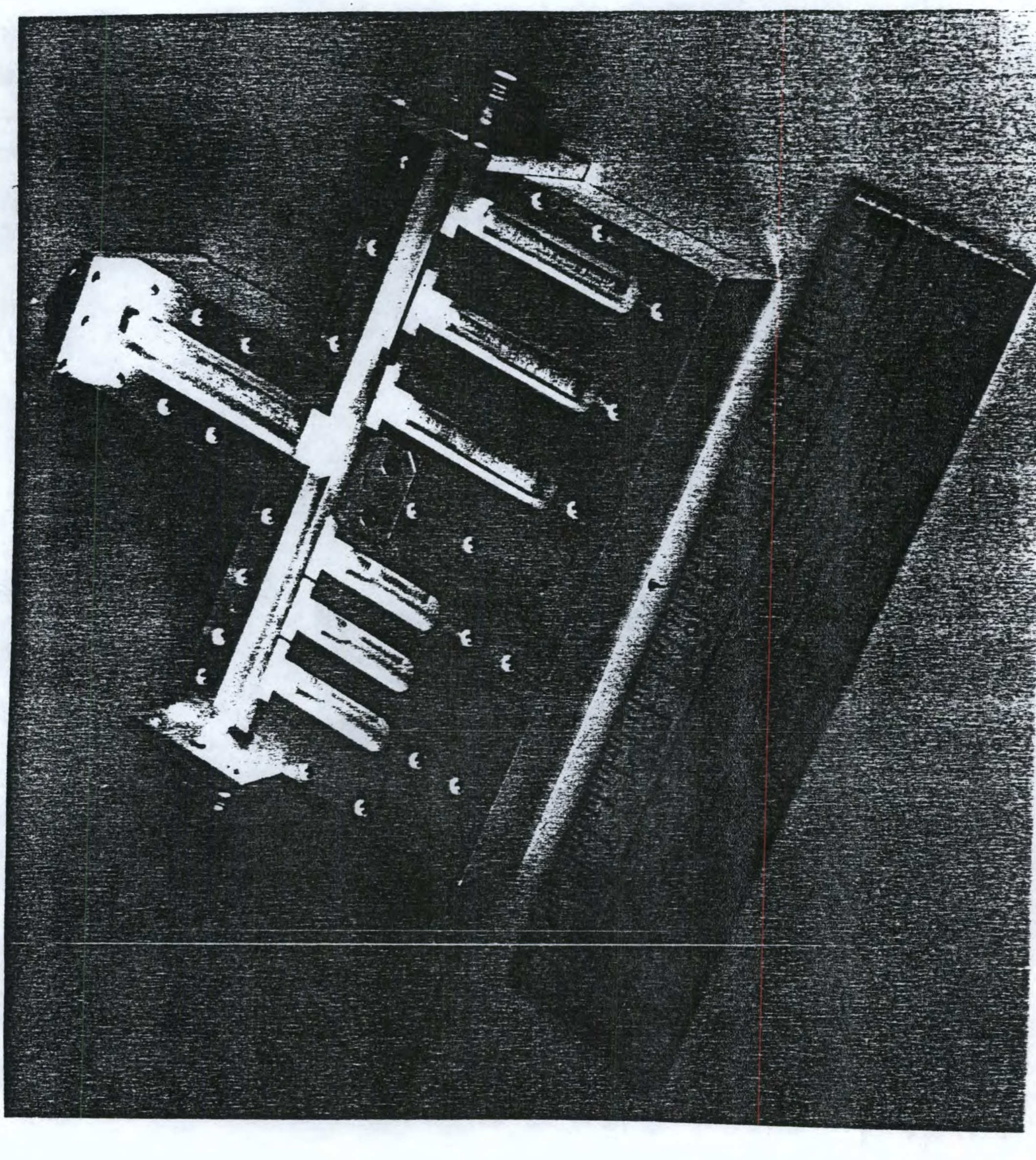


FIG 6.4 ISOLATION IN TRANSMIT BAND

FIG 6.5 TEM LINE C-BAND DUPLEXER

(Central conductor fabricated using EDM)



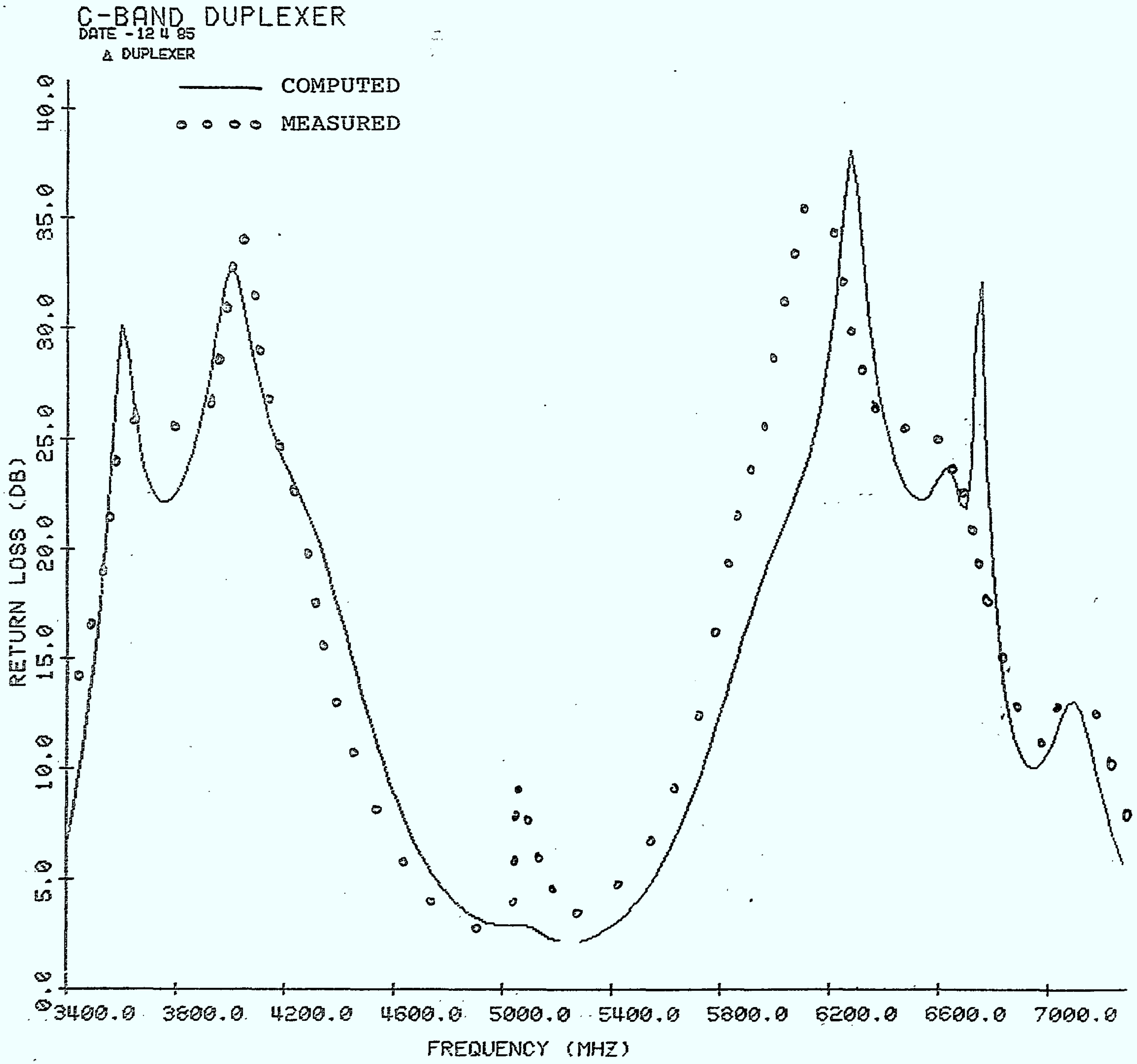


FIG. 6.6 COMPUTED AND MEASURED RETURN LOSS OF DUPLEXER

MEASURED RESULTS OF DUPLEXER

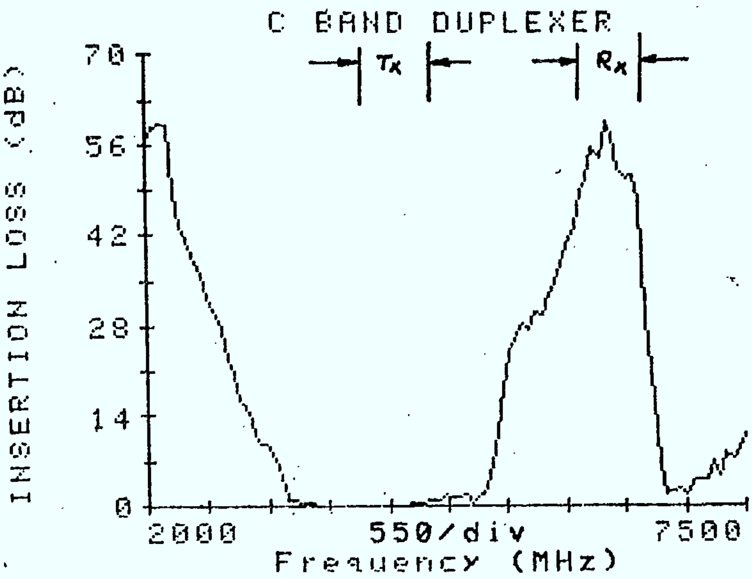


FIG 6.7 TRANSMIT-PORT INSERTION LOSS

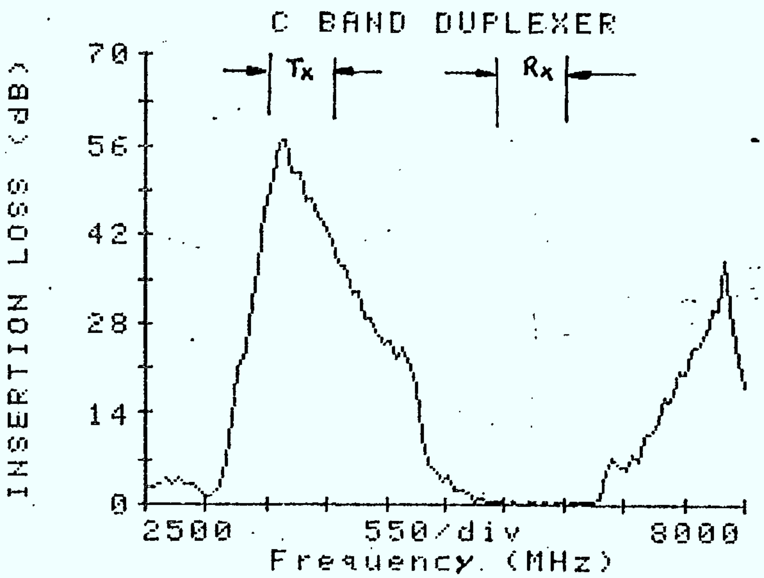


FIG 6.8 RECEIVE PORT INSERTION LOSS

MEASURED RESULTS

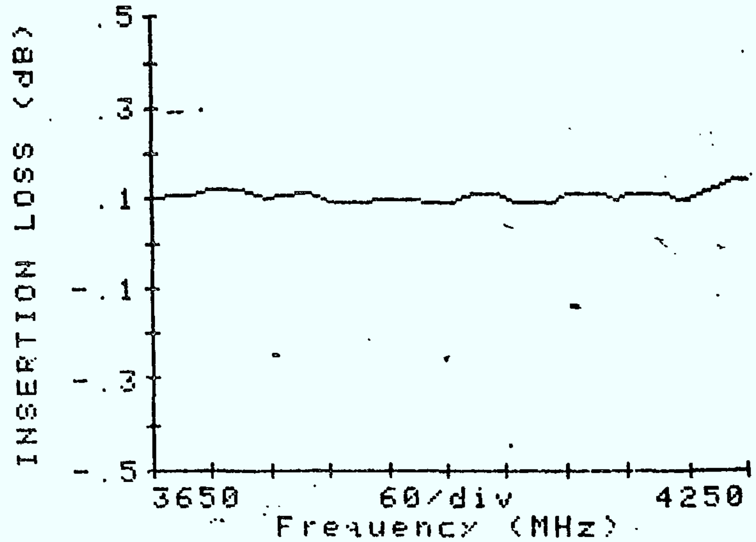


FIG 6.9 TRANSMIT-PORT INBAND LOSS

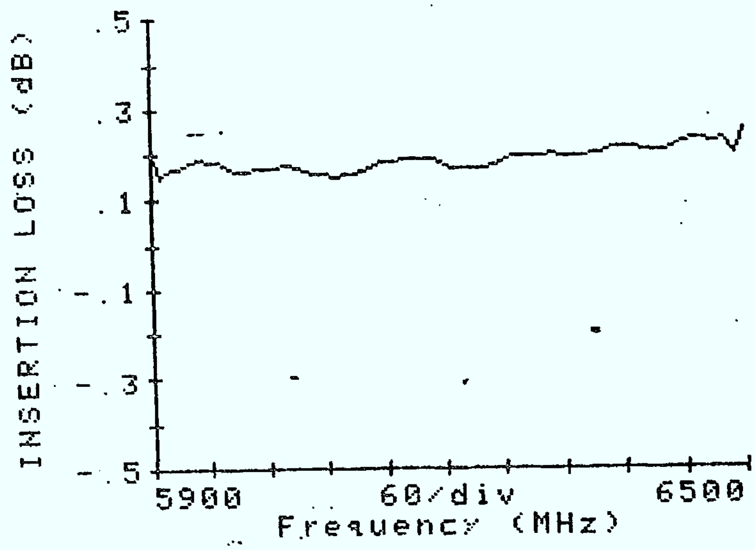


FIG 6.10 RECEIVE-PORT INBAND LOSS

MEASURED RESULTS

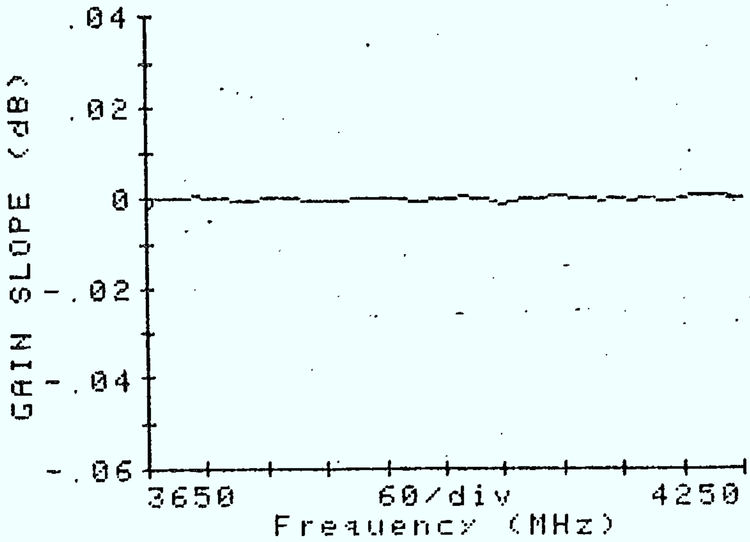


FIG 6.11 TRANSMIT-PORT INBAND GAIN SLOPE

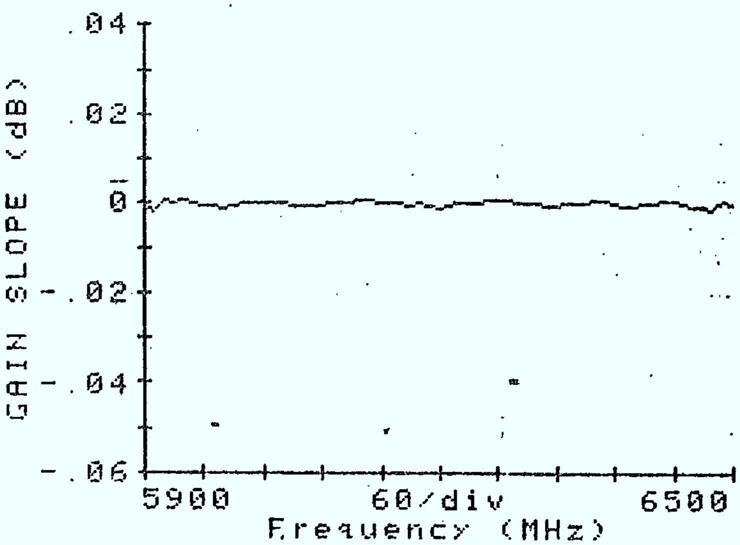


FIG 6.12 RECEIVE-PORT INBAND GAIN SLOPE

7.0 CONCLUSIONS

The development of a duplexer using non-uniform shunt stubs in TEM transmission line medium has been successfully completed. Target performance has been achieved over the operating bandwidth and measured results are comparable with theory.

The design is such that minimum and maximum stub dimensions which can be satisfactorily fabricated using EDM (Electric Discharge Machine) are employed. This type of design has inherent advantage of very significant size reduction and saving in weight in the critical region behind the horns.

Another major objective of this development is to have a design that is relatively unsensitive and therefore requires no tuning. This objective has been met. This is confirmed by close agreement between the results of the various models.

8.0 References

1. Exact Design of Band-Stop Microwave Filters. B.M. Schiffman and G.L. Mathaei, IEEE Transaction on Microwave Theory and Techniques January 1964 pp. 6-15.

2. A design of Wide-Band (and Narrow-Band) Band-Pass Microwave Filters on the Insertion Loss Basis. G.L. Matthaei IRE Transaction on Microwave Theory and Techniques Nov. 1960 pp. 580-593.

3. Microwave band-stop filters with narrow stop-bands. L. Young, G.L. Matthaei, E.M.T. Jones, IRE Trans. on Microwave Theory and Techniques, Vol. 10, pp. 416-427, Nov. 1962.

4. Microwave Filters, Impedance Matching and Coupling Structures, G.L. Matthaei, L. Young, E.M.T. Jones, McGraw-Hill 1964 pp 595-608

5. General Theory and Design of Optimum Quarter-wave TEM line Filters. M.C.Morton, R.J. Wenzel, IEEE Transaction on Microwave Theory and Techniques. May 1965, pp. 316-327.

9.0 Appendix

1) Listing and an example run of program CBDTEM which;

   (a) designs and analyzes prototype filter of any order

   (b) analyzes duplexer by reading input data tape containing receive-transmit filter parameters. The program asks for separation of filters and the characteristic admittance of the connecting line and then prints out return loss of the duplexer. The program can also be run following the prototype design of filters.

2) Listing and an example of program 'SSS1' to analyze phase slope, return loss, transmission loss of a single stepped stub. The program asks for stub admittance and length of stub to be analyzed.

LISTING OF PROGRAM 'CBDTEM'

```
      PROGRAM CBDTEM(INPUT,TAPE1,OUTPUT)
C     THIS PROGRAM DESIGNS AND ANALYSES STEPPED STUB DUPLEXERS
C
C      (BASED ON HALF WAVE STUBS AND QUARTERWAVE CONNECTING LINES,
C     PAGE 605 MATTHAEI, YOUNG, JONES)
C
C
C
C      IMITTANCES ARE ADMITTANCE FOR FILTERS THAT USE SHUNT O.C. ...
C      HALFWAVE STUBS AND IMPEDANCE FOR SERIES S.C. HALFWAVE STUBS.
C      THE PROGRAM ASSUMES THAT THE TWO FILTERS ARE SHUNT CONNECTED...
C      IF THEY ARE MADE OF O.C. SHUNT STUBS AND SERIES CONNECTED IF...
C      THE FILTERS USE SERIES S.C. STUBS .
C      THE VARIABLES NAMED Y*** ARE IMITTANCES ,NOT NECESSARILY ADM-...
      DIMENSION FL(2),FQ(2),FO1(2)
C      ANALYSIS IN TRANSMISSION LINE MEDIUM
      DIMENSION A(20),B(20),G(20),AJ(20),AN(20),YR(2),Y(20),FI(20)
      DIMENSION YD(20),YDD(20),Y1(2,20),Y11(2,20),AJ1(2,20),N1(2)
      COMPLEX AA1(2),AA2(2),AA3(2),AA4(2),YIN1(2),YIN
      COMPLEX AA,CC,AACC
      COMMON A1,A2,A3,A4,B1,B2,B3,B4
      PI=4.*ATAN(1.)
      PRINT 50
 50   FORMAT(*DO YOU WANT TO ANALYSE DUPLEXER USING PARAMETERS ON TAPE1
+     (ENTER 1) OR DESIGN AND ANALYSE NEW FILTERS (ENTER 0)*)
      READ,Q
      IF (Q.EQ.0) GO TO 7000
      DO 77 M=1,2
      READ (1,) N1(M)
      READ (1,) FO1(M)
      N=N1(M)
      DO 777 K=1,N
      READ (1,) Y1(M,K)
      READ (1,) Y11(M,K)
 777  CONTINUE
      N=N1(M)-1
      DO 7777 K=1,N
      READ (1,) AJ1(M,K)
7777  CONTINUE
 77   CONTINUE
      GO TO 522
7000    PRINT 80
 80   FORMAT(/*--------------RECEIVE FILTER----------*)
      M=1
      GOTO 1000
1500  PRINT 90
 90   FORMAT(/*--------------TRANSMIT FILTER---------*)
      M=2
  1000 PRINT 100
  100 FORMAT(/*ENTER ORDER OF THE FILTER*)
      READ, N
     N1(M)=N
      PRINT 110
  110 FORMAT(/*ENTER CENTRE FREQUENCY AND BANDWIDTH (MHZ)*)
      READ,FO,BW
      FO1(M)=FO
```

```
      PRINT 120
120   FORMAT(/*ENTER PASSBAND RIPPLE (DB)*)
      READ, ALAR
CC    COMPUTING G VALUES
      AUX=ALAR/17.37
      BETA=ALOG((EXP(AUX)+EXP(-AUX))/(EXP(AUX)-EXP(-AUX)))
      AUX=BETA/(2.0*N)
      GAMA=(EXP(AUX)-EXP(-AUX))/2.0
      DO 150 K=1,N
      A(K)=SIN((2.0*K-1.0)*PI/(2.0*N))
      B(K)=GAMA**2+(SIN(K*PI/N))**2
150   CONTINUE
      G(1)=2.0*A(1)/GAMA
      DO 160 K=2,N
      G(K)=4*A(K-1)*A(K)/(B(K-1)*G(K-1))
160   CONTINUE
      G(N+1)=1.0
      AUX=N-2.0*INT(N/2.0)
      IF(AUX.NE.0) GO TO 600
      AUX=BETA/4.0
      G(N+1)=((EXP(AUX)+EXP(-AUX))/(EXP(AUX)-EXP(-AUX)))**2
CC    COMPUTING CONNECTING LINE/STUB IMITTANCES
600   PRINT 130
130   FORMAT(/*ENTER IMITTANCE LEVEL FACTOR D (O(D(=1.0)*)
      READ, D
      PRINT 131
131   FORMAT(/,*OBS-IMITTANCES ARE ADMITTANCES FOR SHUNT STUB*,/,
+     *FILTERS, IMPEDANCES FOR SERIES STUB FILTERS, NORMALIZED*,/,
+     *TO INPUT AND OUTPUT IMITTANCES*)
200   TET1=(1.0-BW/(2.0*FO))*PI/2.0
      TT1=TAN(TET1)
      TT1S=TT1**2
      CA=2.0*D*G(1)
      AJ(1)=SQRT(CA/G(2))
      AJ1(M,1)=AJ(1)
      IF(N.LE.3) GO TO 230
      I=N-2
      DO 220 K=2,I
      AJ(K)=CA/SQRT(G(K)*G(K+1))
      AJ1(M,K)=AJ(K)
220   CONTINUE
230   IF(N.LE.2) GO TO 240
      AJ(N-1)=SQRT(CA*G(N+1)/G(N-1))
      AJ1(M,N-1)=AJ(N-1)
      I=N-1
240   DO 250 K=1,I
      AN(K)=SQRT(AJ(K)**2+(CA*TT1/2.0)**2)
250   CONTINUE
      Y(1)=(1-D)*G(1)*TT1+AN(1)-AJ(1)
      IF(N.LE.2) GO TO 270
      DO 260 K=2,I
      Y(K)=AN(K-1)+AN(K)-AJ(K-1)-AJ(K)
260   CONTINUE
270   Y(N)=(G(N)*G(N+1)-D*G(1))*TT1+AN(N-1)-AJ(N-1)
      PRINT 300
300   FORMAT(//16X,*CHARACT. IMITTANCES OF THE STUBS,*,/,
```

```
+          16X,*QUARTER WAVELENGTH STUB PROTOTYPE*)
           DO 340 K=1,N
           PRINT 330,K,Y(K)
     330   FORMAT(20X,*Y(*,I2,*)=*,F12.4)
     340   CONTINUE
           PRINT 400
     400   FORMAT(/16X,*CHARACTERISTIC IMITTANCES OF THE CONNECTING LINES*)
           DO 440 K=1,I
           L=K+1
           PRINT 430, K, L, AJ(K)
     430   FORMAT(20X,*Y(*,I2,*,*,I2,*)=*,F12.4)
     440   CONTINUE
           PRINT 500
     500   FORMAT(/*DO YOU WANT TO CHANGE IMITTANCE LEVEL FACTOR D?*)
           PRINT 505
     505   FORMAT(* 1=YES      2=NO*)
           READ,L
           IF(L.EQ.2) GO TO 310
    480    PRINT 320,D
    320    FORMAT(/*PREVIOUS VALUE OF D=*,F6.2)
           GO TO 600
C          STEPPING FILTER STUB IMITTANCES
     310   PRINT 710
     710   FORMAT(/*ENTER INF.ATTEN.FREQUENCIES (MHZ)*)
           DO 140 K=1,N
           PRINT 720,K
     720   FORMAT(5X,*STUB (*,I2,*)=*)
           READ,FI(K)
     140   CONTINUE
           DO 170 K=1,N
           AUX=(1./TAN(PI*FI(K)/2./FO))**2
           YD(K)=Y(K)*(AUX*TT1S-1.)/(AUX+1.)/TT1S
           YDD(K)=YD(K)*AUX
           Y1(M,K)=YD(K)
           Y11(M,K)=YDD(K)
     170   CONTINUE
           PRINT 180
     180   FORMAT(//16X,*CHARACTERISTIC IMITTANCES OF THE STEPPED STUBS*)
           DO 190 K=1,N
           PRINT 210,K,YD(K),K,YDD(K)
     210   FORMAT(20X,*YD(*,I2,*)=*,F12.4,5X,*YDD(*,I2,*)=*,F12.4)
    190    CONTINUE
           PRINT 280
    280    FORMAT(/*DO YOU WANT TO CHANGE INF.ATTEN.FREQUENCIES?*)
           PRINT 290
    290    FORMAT(*1=YES       2=NO*)
           READ,L
           IF(L.EQ.2) GO TO 410
    490    PRINT 420
    420    FORMAT(/*PREVIOUS INF.ATTEN.FREQUENCIES (MHZ)*)
           DO 460 K=1,N
           PRINT 470,K,FI(K)
    470    FORMAT(5X,*STUB (*I2,*)=*,F10.1)
    460    CONTINUE
           GO TO 310
    410    PRINT 411
```

```
 411   FORMAT(/*DO YOU WANT TO CHANGE FILTER PARAMETERS? 1=YES 2=NO*)
       READ,L
      IF(L.NE.2) GO TO 1000
       PRINT 500
       PRINT 505
       READ,L
       IF(L.NE.2) GO TO 480
C      *--------ANALYSIS OF FILTER---------*
  354 PRINT 355
 355   FORMAT(*ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS*)
       READ,F1,F2,DELF
       PRINT 390
 390   FORMAT(//16X,*FREQ (MHZ)*,5X,*RLOSS (DB)*,5X,*TLOSS (DB)*)
       F=F1
 360   CO=COS(F/FO*PI/2.)
       SI=SIN(F/FO*PI/2.)
       CT=CO/SI
       A1=1
       A2=0
       A3=(YD(1)+YDD(1))/(CT-YDD(1)/YD(1)/CT)
       A4=1
       DO 370 K=2,N
       B1=CO
       B2=SI/AJ(K-1)
       B3=SI*AJ(K-1)
       B4=CO
       CALL AB(A1,A2,A3,A4,B1,B2,B3,B4)
       B1=1
       B2=0
       B3=(YD(K)+YDD(K))/(CT-YDD(K)/YD(K)/CT)
       B4=1
       CALL AB(A1,A2,A3,A4,B1,B2,B3,B4)
 370   CONTINUE
       AR=A1+A4
       AI=A2+A3
       AA=CMPLX(AR,AI)
       CC=CMPLX(A4,A3)
       AACC=AA-2.*CC
       ACMOD=CABS(AACC)
       AMOD=CABS(AA)
       RL=20.*ALOG10(AMOD/ACMOD)
       TL=20.*ALOG10(AMOD/2)
       PRINT 380,F,RL,TL
  380  FORMAT(/8X,3(5X,F10.2))
       F=F+DELF
       IF(F.LE.F2) GO TO 360
       PRINT 521
  521  FORMAT(*DO YOU WANT ANOTHER FREQ ANALYSIS? 1=YES 2=NO*)
       READ,L
       IF(L.EQ.1) GO TO 354
        PRINT 524
  524   FORMAT(*DO WANT ANOTHER FILTER ANALYSIS? 1=YES  2=NO*)
        READ,L
        IF(L.EQ.1) GO TO 1500
  522   PRINT 518
 518   FORMAT(/*------------DUPLEXER ANALYSIS---------*)
```

```
  530 PRINT 350
  350 FORMAT(/*ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS*)
      READ,F1,F2,DELF
      FQ(1)=F1
      FQ(2)=F1
  392 FORMAT(//16X,*FREQUENCY (MHZ)*,5X,*RETURN LOSS (DB)*)
      PRINT 3000
 3000 FORMAT(//*ENTER LENGHT FOR RX FILTER AND ADMITANCE*)
      READ,FRX,YRX
      FL(1)=FRX
      YR(1)=YRX
      PRINT 3500
 3500 FORMAT(/*ENTER LENGHT FOR TX FILTER AND ADMITANCE*)
      READ,FTX,YTX
      FL(2)=FTX
      YR(2)=YTX
      PRINT 392
 4000 M=1
      F=FQ(M)
      GOTO 5000
 4500 M=2
      F=FQ(M)
 5000 N=N1(M)
      FO=FO1(M)
      DO 4100 K=1,N
      YD(K)=Y1(M,K)
      YDD(K)=Y11(M,K)
      AJ(K)=AJ1(M,K)
 4100 CONTINUE
      WLF=29979.25/2.54/F
      CO=COS(F/FO*PI/2.)
      SI=SIN(F/FO*PI/2.)
      CT=CO/SI
      CO1=COS((2.*PI/WLF)*FL(M))
      SI1=SIN((2.*PI/WLF)*FL(M))
      A1=CO1
      A2=SI1/YR(M)
      A3=SI1*YR(M)
      A4=CO1
      B1=1.
      B2=0
      B3=YD(1)*(YD(1)+YDD(1))/(YD(1)*CT-YDD(1)/CT)
      B4=1.
      CALL AB(A1,A2,A3,A4,B1,B2,B3,B4)
      DO 372 K=2,N
      B1=CO
      B2=SI/AJ(K-1)
      B3=SI*AJ(K-1)
      B4=CO
      CALL AB(A1,A2,A3,A4,B1,B2,B3,B4)
      B1=1.
      B2=0
      B3=YD(K)*(YD(K)+YDD(K))/(YD(K)*CT-YDD(K)/CT)
      B4=1.
      CALL AB(A1,A2,A3,A4,B1,B2,B3,B4)
  372 CONTINUE
```

```
87    FORMAT(8X,2(8X,F10.2))
       AA1(M)=CMPLX(A1,0.0)
       AA2(M)=CMPLX(0.0,A2)
       AA3(M)=CMPLX(0.0,A3)
       AA4(M)=CMPLX(A4,0.0)
       YIN1(M)=(AA3(M)+AA4(M))/(AA1(M)+AA2(M))
        AAA=AA1(1)+AA1(2)
        BBB=AA2(1)+AA2(2)
        CCC=AA3(1)+AA3(2)
        DDD=AA4(1)+AA4(2)
        IF(M.EQ.1) GO TO 5500
       YIN=YIN1(1)+YIN1(2)
       REFL=CABS((YIN+CMPLX(1.,0.))/(YIN-CMPLX(1.,0.)))
       RLOSS=20.*ALOG10(REFL)
      PRINT 87,F,RLOSS
5500   FQ(M)=FQ(M)+DELF
       IF (FQ(2).LE.F2.AND.M.EQ.1) GO TO 4500
       IF (FQ(2).LE.F2.AND.M.EQ.2) GO TO 4000
       PRINT 520
  520  FORMAT(/*DO YOU WANT ANOTHER FREQ. ANALYSIS?  1=YES  2=NO*)
       READ,L
       IF(L.NE.2) GO TO 530
       STOP
       END
       SUBROUTINE AB(A1,A2,A3,A4,B1,B2,B3,B4)
C      MATRIX MULTIPLICATION A*B
       C1=A1*B1-A2*B3
       C2=A1*B2+A2*B4
       C3=A3*B1+A4*B3
       C4=-A3*B2+A4*B4
       A1=C1 $ A2=C2 $ A3=C3 $ A4=C4
       RETURN
       END
```

LISTING OF PROGRAM 'SSS1' (COMPUTES PHASE-SLOPE OF A STEPPED STUB)

```
       PROGRAM SSS1 (INPUT,OUTPUT)
CC     THIS PROGRAM ANALYSES SHUNT STEPPED STUB 1 SECTION
CC     (BASED ON HALF WAVE STUBS AND QUARTER WAVE SPACINGS, PAGE  605
CC     MATTHAEI,YOUNG JONES.)
         COMPLEX A,C,AC
          DIMENSION APH(101)
        COMMON A1,A2,A3,A4,B1,B2,B3,B4
         PI=4.*ATAN(1.)
         PRINT 100
  100    FORMAT(/*ENTER FSTART, FSTOP, DELF (MHZ)*)
         READ,F1,F2,DELF
         PRINT 110
  110    FORMAT(/*ENTER LINE LENGTH (INCH)*)
        READ,EL,ELS
         PRINT 120
 120    FORMAT(/*ENTER Y1D Y1DD*)
        READ,Y1D,Y1DD
         CEE=29.97925E+3
         PRINT 130
 130    FORMAT(//16X,*FREQ MHZ*,5X,*RLOSS (DB)*,5X,*TLOSS (DB)*,5X,
++*PHASE (DEG)*)
         F=F1
           I=1
  150    XLO=CEE/F/2.54
         BETA=2.*PI/XLO
         CO=COS(BETA*EL)
         SI=SIN(BETA*EL)
        CO2=COS(BETA*ELS)
        SI2=SIN(BETA*ELS)
        CT2=SI2/CO2
        CT=CO/SI
       Y1IN=(Y1D+Y1DD)/(CT-Y1DD/Y1D/CT)
         A1=1.0
         A2=0
        A3=Y1IN
          A4=1.0
         AR=A1+A4
         AI=A2+A3
         A=CMPLX(AR,AI)
         C=CMPLX(A4,A3)
         AC=A-2*C
         ACMOD=CABS(AC)
         AMOD=CABS(A)
         RL=20.*ALOG10(AMOD/ACMOD)
         TL=20.*ALOG10(AMOD/2.)
        APH(I)=-1*ATAN2(AI,AR)*180/PI
           PRINT 140,F,RL,TL,APH(I)
 140    FORMAT(/8X,4(5X,F10.2))
         F=F+DELF
          I=I+1
         IF(F.LE.F2) GO TO 150
         STOP
         END
         SUBROUTINE AB(A1,A2,A3,A4,B1,B2,B3,B4)
CC     MATRIX MULTICATION A * B
         C1=A1*B1-A2*B3
```

```
      C2=A1*B2+A2*B4
      C3=A3*B1+A4*B3
      C4=-A3*B2+A4*B4
      A1=C1 $ A2=C2 $ A3=C3 $ A4=C4
      RETURN
      END
```

COMPUTER RUN OF RECEIVE-FILTER DESIGN (PROGRAM CBDTEM)

```
 BATCH
$RFL,0.
/CFORT,I=CBDTEM,L=0,LN
  027000  OCTAL REQUIRED
/LGO
DO YOU WANT TO ANALYSE DUPLEXER USING PARAMETERS ON TAPE1
? 0

-------------RECEIVE FILTER---------

ENTER ORDER OF THE FILTER
? 3

ENTER CENTRE FREQUENCY AND BANDWIDTH (MHZ)
? 6175 950

ENTER PASSBAND RIPPLE (DB)
? .01

ENTER IMITTANCE LEVEL FACTOR D (0<D<=1.0)
? .9

OBS-IMITTANCES ARE ADMITTANCES FOR SHUNT STUB
FILTERS, IMPEDANCES FOR SERIES STUB FILTERS, NORMALIZED
TO INPUT AND OUTPUT IMITTANCES

                CHARACT.IMITTANCES OF THE STUBS,
                QUARTER WAVELENGTH STUB PROTOTYPE
                    Y( 1)=        4.2250
                    Y( 2)=        7.4136
                    Y( 3)=        4.2250

                CHARACTERISTIC IMITTANCES OF THE CONNECTING LINES
                    Y( 1, 2)=        1.0804
                    Y( 2, 3)=        1.0804

DO YOU WANT TO CHANGE IMITTANCE LEVEL FACTOR D?
 1=YES       2=NO
? 2

ENTER INF.ATTEN.FREQUENCIES (MHZ)
     STUB ( 1)=
? 3700
     STUB ( 2)=
? 4150
     STUB ( 3)=
? 3900

                CHARACTERISTIC IMITTANCES OF THE STEPPED STUBS
                    YD( 1)=        1.4241     YDD( 1)=        .7558
                    YD( 2)=        1.7165     YDD( 2)=        .5501
                    YD( 3)=        1.2203     YDD( 3)=        .5209

DO YOU WANT TO CHANGE INF.ATTEN.FREQUENCIES?
1=YES        2=NO
? 2
```

```
DO YOU WANT TO CHANGE FILTER PARAMETERS? 1=YES 2=NO
? 2

DO YOU WANT TO CHANGE IMITTANCE LEVEL FACTOR D?
 1=YES        2=NO
? 2
ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS
? 5725 6625 25
```

FREQ (MHZ)	RLOSS (DB)	TLOSS (DB)
5725.00	31.43	.00
5750.00	42.93	.00
5775.00	40.74	.00
5800.00	33.01	.00
5825.00	29.71	.00
5850.00	27.86	.01
5875.00	26.77	.01
5900.00	26.18	.01
5925.00	25.94	.01
5950.00	26.00	.01
5975.00	26.33	.01
6000.00	26.92	.01
6025.00	27.80	.01
6050.00	29.02	.01
6075.00	30.66	.00
6100.00	32.95	.00
6125.00	36.31	.00
6150.00	42.25	.00
6175.00	278.92	-.00
6200.00	42.25	.00
6225.00	36.31	.00
6250.00	32.95	.00
6275.00	30.66	.00

6300.00	29.02	.01
6325.00	27.80	.01
6350.00	26.92	.01
6375.00	26.33	.01
6400.00	26.00	.01
6425.00	25.94	.01
6450.00	26.18	.01
6475.00	26.77	.01
6500.00	27.86	.01
6525.00	29.71	.00
6550.00	33.01	.00
6575.00	40.74	.00
6600.00	42.93	.00
6625.00	31.43	.00

```
DO YOU WANT ANOTHER FREQ ANALYSIS? 1=YES 2=NO
? 1
ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS
? 3500 4400 25
```

FREQ (MHZ)	RLOSS (DB)	TLOSS (DB)
3500.00	.00	35.60
3525.00	.00	38.28
3550.00	.00	41.15
3575.00	.00	44.28
3600.00	.00	47.81
3625.00	.00	51.94
3650.00	.00	57.16
3675.00	.00	64.97
3700.00	0.00	302.54
3725.00	.00	68.88
3750.00	.00	65.08
3775.00	.00	64.03

3800.00	.00	64.39
3825.00	.00	65.89
3850.00	.00	68.80
3875.00	.00	74.50
3900.00	0.00	308.58
3925.00	.00	74.54
3950.00	.00	68.84
3975.00	.00	65.86
4000.00	.00	64.13
4025.00	.00	63.26
4050.00	.00	63.13
4075.00	.00	63.85
4100.00	.00	65.79
4125.00	.00	70.39
4150.00	0.00	310.55
4175.00	.00	67.91
4200.00	.00	60.78
4225.00	.00	56.23
4250.00	.00	52.75
4275.00	.00	49.89
4300.00	.00	47.43
4325.00	.00	45.26
4350.00	.00	43.29
4375.00	.00	41.50
4400.00	.00	39.83

```
DO YOU WANT ANOTHER FREQ ANALYSIS? 1=YES 2=NO
? 2
DO WANT ANOTHER FILTER ANALYSIS? 1=YES  2=NO
? 1
```

COMPUTER RUN OF TRANSMIT-FILTER DESIGN (PROGRAM CBDTEM)

```
--------------TRANSMIT FILTER--------

ENTER ORDER OF THE FILTER
? 3

ENTER CENTRE FREQUENCY AND BANDWIDTH (MHZ)
? 4100 900

ENTER PASSBAND RIPPLE (DB)
? .01

ENTER IMITTANCE LEVEL FACTOR D (0<D<=1.0)
? .43

OBS-IMITTANCES ARE ADMITTANCES FOR SHUNT STUB
FILTERS, IMPEDANCES FOR SERIES STUB FILTERS, NORMALIZED
TO INPUT AND OUTPUT IMITTANCES

                CHARACT.IMITTANCES OF THE STUBS,
                QUARTER WAVELENGTH STUB PROTOTYPE
                    Y( 1)=       3.0367
                    Y( 2)=       1.9542
                    Y( 3)=       3.0367

                CHARACTERISTIC IMITTANCES OF THE CONNECTING LINES
                    Y( 1, 2)=         .7468
                    Y( 2, 3)=         .7468

DO YOU WANT TO CHANGE IMITTANCE LEVEL FACTOR D?
 1=YES      2=NO
? 2

ENTER INF.ATTEN.FREQUENCIES (MHZ)
     STUB ( 1)=
? 5950
     STUB ( 2)=
? 6400
     STUB ( 3)=
? 6200

                CHARACTERISTIC IMITTANCES OF THE STEPPED STUBS
                    YD( 1)=      1.2335     YDD( 1)=       .9068
                    YD( 2)=      1.1391     YDD( 2)=      1.6749
                    YD( 3)=      1.5322     YDD( 3)=      1.6543

DO YOU WANT TO CHANGE INF.ATTEN.FREQUENCIES?
1=YES       2=NO
? 2

DO YOU WANT TO CHANGE FILTER PARAMETERS? 1=YES 2=NO
? 2
```

COMPUTER RUN OF TRANSMIT-FILTER ANALYSIS

```
DO YOU WANT TO CHANGE IMITTANCE LEVEL FACTOR D?
 1=YES       2=NO
? 2
ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS
? 3500 4400 25
```

FREQ (MHZ)	RLOSS (DB)	TLOSS (DB)
3500.00	9.51	.52
3525.00	10.93	.37
3550.00	12.51	.25
3575.00	14.25	.17
3600.00	16.19	.11
3625.00	18.39	.06
3650.00	20.91	.04
3675.00	23.92	.02
3700.00	27.70	.01
3725.00	33.01	.00
3750.00	43.26	.00
3775.00	44.80	.00
3800.00	36.25	.00
3825.00	32.93	.00
3850.00	31.23	.00
3875.00	30.37	.00
3900.00	30.07	.00
3925.00	30.22	.00
3950.00	30.77	.00
3975.00	31.74	.00
4000.00	33.21	.00
4025.00	35.37	.00
4050.00	38.65	.00

COMPUTER RUN OF TRANSMIT-FILTER ANALYSIS

4075.00	44.53	.00
4100.00	283.68	-.00
4125.00	44.53	.00
4150.00	38.65	.00
4175.00	35.37	.00
4200.00	33.21	.00
4225.00	31.74	.00
4250.00	30.77	.00
4275.00	30.22	.00
4300.00	30.07	.00
4325.00	30.37	.00
4350.00	31.23	.00
4375.00	32.93	.00
4400.00	36.25	.00

```
DO YOU WANT ANOTHER FREQ ANALYSIS? 1=YES 2=NO
? 1
ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS
? 5725 6625 25
```

FREQ (MHZ)	RLOSS (DB)	TLOSS (DB)
5725.00	.00	35.73
5750.00	.00	37.42
5775.00	.00	39.27
5800.00	.00	41.33
5825.00	.00	43.66
5850.00	.00	46.39
5875.00	.00	49.72
5900.00	.00	54.13
5925.00	.00	61.10
5950.00	-.00	315.53

5975.00	.00	63.25
6000.00	.00	58.47
6025.00	.00	56.34
6050.00	.00	55.43
6075.00	.00	55.35
6100.00	.00	56.00
6125.00	.00	57.50
6150.00	.00	60.74
6175.00	.00	65.68
6200.00	-.00	314.23
6225.00	.00	65.07
6250.00	.00	59.07
6275.00	.00	55.83
6300.00	.00	53.98
6325.00	.00	53.26
6350.00	.00	53.90
6375.00	.00	57.27
6400.00	-.00	305.22
6425.00	.00	52.58
6450.00	.00	44.02
6475.00	.00	38.19
6500.00	.00	33.38
6525.00	.01	29.10
6550.00	.01	25.12
6575.00	.03	21.29
6600.00	.08	17.53
6625.00	.19	13.78

```
DO YOU WANT ANOTHER FREQ ANALYSIS? 1=YES 2=NO
? 2
DO WANT ANOTHER FILTER ANALYSIS? 1=YES  2=NO
? 2
```

COMPUTER RUN OF DUPLEXER ANALYSIS USING DATA FILE (PROGRAM CBDTEM)

```
 OLD,CBDIPX2    (DATA FILE CONTAINING FILTERS PARAMETERS)
/LIST
3
6175
1.424
.7558
1.7164
.5501
1.2203
.5209
1
1
3
4100
1.532
1.654
1.139
1.675
1.2335
.9068
.7468
.7468

/GET,TAPE1=CBDIPX2
/GET,CBDTEM
/BEGIN,,PP,CBDTEM
DO YOU WANT TO ANALYSE DUPLEXER USING PARAMETERS ON TAPE1
? 1

------------DUPLEXER ANALYSIS---------

ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS
? 5725 6625 25


ENTER LENGHT FOR RX FILTER AND ADMITANCE
? .695 1.03

ENTER LENGHT FOR TX FILTER AND ADMITANCE
? .485 1.01
```

FREQUENCY (MHZ)	RETURN LOSS (DB)
5725.00	10.66
5750.00	11.73
5775.00	12.86
5800.00	14.04
5825.00	15.26
5850.00	16.50
5875.00	17.74
5900.00	18.95
5925.00	20.10
5950.00	21.18
5975.00	22.17
6000.00	23.10

SPAR

COMPUTER RUN OF DUPLEXER ANALYSIS

6025.00	24.02
6050.00	24.99
6075.00	26.08
6100.00	27.40
6125.00	29.08
6150.00	31.32
6175.00	34.36
6200.00	37.79
6225.00	37.36
6250.00	33.37
6275.00	29.88
6300.00	27.22
6325.00	25.15
6350.00	23.49
6375.00	22.14
6400.00	21.05
6425.00	20.18
6450.00	19.50
6475.00	19.00
6500.00	18.67
6525.00	18.51
6550.00	18.52
6575.00	18.66
6600.00	18.86
6625.00	18.88

```
DO YOU WANT ANOTHER FREQ. ANALYSIS?  1=YES  2=NO
? 1

ENTER FSTART, FSTOP, DELF (MHZ) FOR ANALYSIS
? 3500 4400 25

ENTER LENGHT FOR RX FILTER AND ADMITANCE
? .695 1.03

ENTER LENGHT FOR TX FILTER AND ADMITANCE
? .485 1.01
```

FREQUENCY (MHZ)	RETURN LOSS (DB)
3500.00	15.56
3525.00	18.51
3550.00	21.71
3575.00	24.53
3600.00	25.61
3625.00	24.92
3650.00	23.81
3675.00	22.95
3700.00	22.43
3725.00	22.24
3750.00	22.34
3775.00	22.71
3800.00	23.33

DUPLEXER ANALYSIS (CONT)

3825.00	24.22
3850.00	25.39
3875.00	26.87
3900.00	28.73
3925.00	30.93
3950.00	33.14
3975.00	34.15
4000.00	33.05
4025.00	31.01
4050.00	29.06
4075.00	27.43
4100.00	26.13
4125.00	25.07
4150.00	24.21
4175.00	23.49
4200.00	22.85
4225.00	22.26
4250.00	21.66
4275.00	21.01
4300.00	20.27
4325.00	19.43
4350.00	18.50
4375.00	17.49
4400.00	16.43

```
DO YOU WANT ANOTHER FREQ. ANALYSIS?  1=YES  2=NO
? 2
$REVERT.CCL
```

COMPUTER RUN OF PROGRAM 'SSS1'

(Example of receive-filter stub phase-slope)

```
 OLD,SSS1
/BATCH
$RFL,0.
/CFORT,I=SSS1,L=0,LN
  020500  OCTAL REQUIRED
/LGO

ENTER FSTART, FSTOP, DELF (MHZ)
? 5925 6425 25

ENTER LINE LENGTH (INCH)
? .478 .478

ENTER Y1D Y1DD
? 1.7165 .5501
```

FREQ MHZ	RLOSS (DB)	TLOSS (DB)	PHASE (DEG)
5925.00	13.12	.22	12.75
5950.00	14.03	.18	11.47
5975.00	15.04	.14	10.19
6000.00	16.20	.11	8.91
6025.00	17.54	.08	7.62
6050.00	19.14	.05	6.34
6075.00	21.10	.03	5.05
6100.00	23.65	.02	3.76
6125.00	27.29	.01	2.48
6150.00	33.67	.00	1.19
6175.00	55.08	.00	-.10
6200.00	32.30	.00	-1.39
6225.00	26.61	.01	-2.68
6250.00	23.20	.02	-3.97
6275.00	20.76	.04	-5.25
6300.00	18.87	.06	-6.54
6325.00	17.32	.08	-7.83
6350.00	16.01	.11	-9.11
6375.00	14.88	.14	-10.39
6400.00	13.88	.18	-11.67
6425.00	12.99	.22	-12.95

```
STOP
/
```