AUTOMATIC ANTENNA SWITCHING DESIGN FOR
EXTRA VEHICULAR ACTIVITY (EVA)
COMMUNICATION SYSTEM

Final Report

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ABSTRACT

An Extra Vehicular Activity (EVA) crewmember has two-way communications with the Space Station in the Ku-band frequency (12-18 GHz). The maximum range of the EVA communications link with the Space Station is approximately one kilometer for nominal values for transmitter power, antenna gains, and receiver noise figure. The EVA Communications System, that will continue to function regardless of the astronaut's position and orientation, requires an antenna system that has a full spherical coverage. Three or more antennas that can be flush mounted on the astronaut's space suit (EMU) and/or his propulsive backpack (MMU), will be needed to provide the desired coverage.

As the astronaut moves in the Space Station, the signal received by a given EVA antenna changes. An automatic antenna switching system is needed that will switch the communication system to the antenna with the largest signal strength. A design for automatic antenna switching is presented and discussed.

INTRODUCTION

The EVA crewmember will be working on the Space Station, examining and repairing different systems and components. He will be communicating with the base station using his transceiver in the Ku-band frequency. A reliable communication link between EVA and Space Station needs to be established for various positions and orientations of the EVA crewmember. A spherical coverage will be desired to establish the reliable communication link. A multiple wide-beamwidth antenna system is needed to provide the desired spherical coverage. The number of antennas needed and their optimum positions where they can be flush mounted on the crewmember's life support system (EMU) and/or his propulsive backpack, need to be studied. Mr. John C. Ngo of the Electromagnetic Systems Branch at NASA/JSC has studied various antennas for the Ku-band and their radiation patterns. He plans to study the number of antennas needed and their optimum locations on the mock-up model of the space suit and the backpack in the very near future.

The strength of the signal received by the EVA antenna from the Space Station will change as the crewmember moves. When the signal strength received by a particular EVA antenna falls below a certain threshold level, there is a need to switch to the EVA antenna that has the strongest received signal. An automatic antenna switching system is desired to accomplish this task. A scheme for this

switching is shown in Figure 1   . The top part of Figure 1 shows
a transmitter(TX)/receiver(RX) module for the EVA radio connected
through a circulator to a microwave single-pole multi-throw PIN
diode switch, which has been connected to four different omni
antennas. When the signal strength received by a certain EVA
antenna falls below a threshold as indicated by the AGC level, the
signal processor which is a programmed computer, will send a command
signal to a microwave sampling switch that has been connected to 10
dB directional couplers that are coupled to the omni antennas. The
microwave PIN diode sampling switch that is shown in the bottom part
of Figure 1 will start sampling the received signals from various
antennas. These samples in the - 110 to - 70 dBm power range will
pass through a 13.4 - 13.7 GHz bandpass filter (BPF), a low noise
amplifier (LNA), and a Ku-band mixer that will down convert the
samples into the 450 - 750 Mhz UHF range. This 300 MHz wide range
has seven different 40 MHz wide channels assigned to different
users. A suitable BPF (40 MHz) will pick out the right channel for
the user and pass it to a second mixer that will convert it down to
70 MHz IF signal in the 50 - 90 MHz range at - 80 to - 30 dBm power
level. This 40 MHz wide channel consists of three subchannels, a 22
MHz wide live video channel in the return link, a 300 KHz wide low
rate video or voice or data channel, and a 800 KHz wide data rate
channel in the forward link. The synthesized local oscillator will
pick out the low data rate channel. The IF signal is passed through
a 70 MHz bandpass filter, that was designed and built, and is then
fed to a signal level detector. The block diagram of this signal
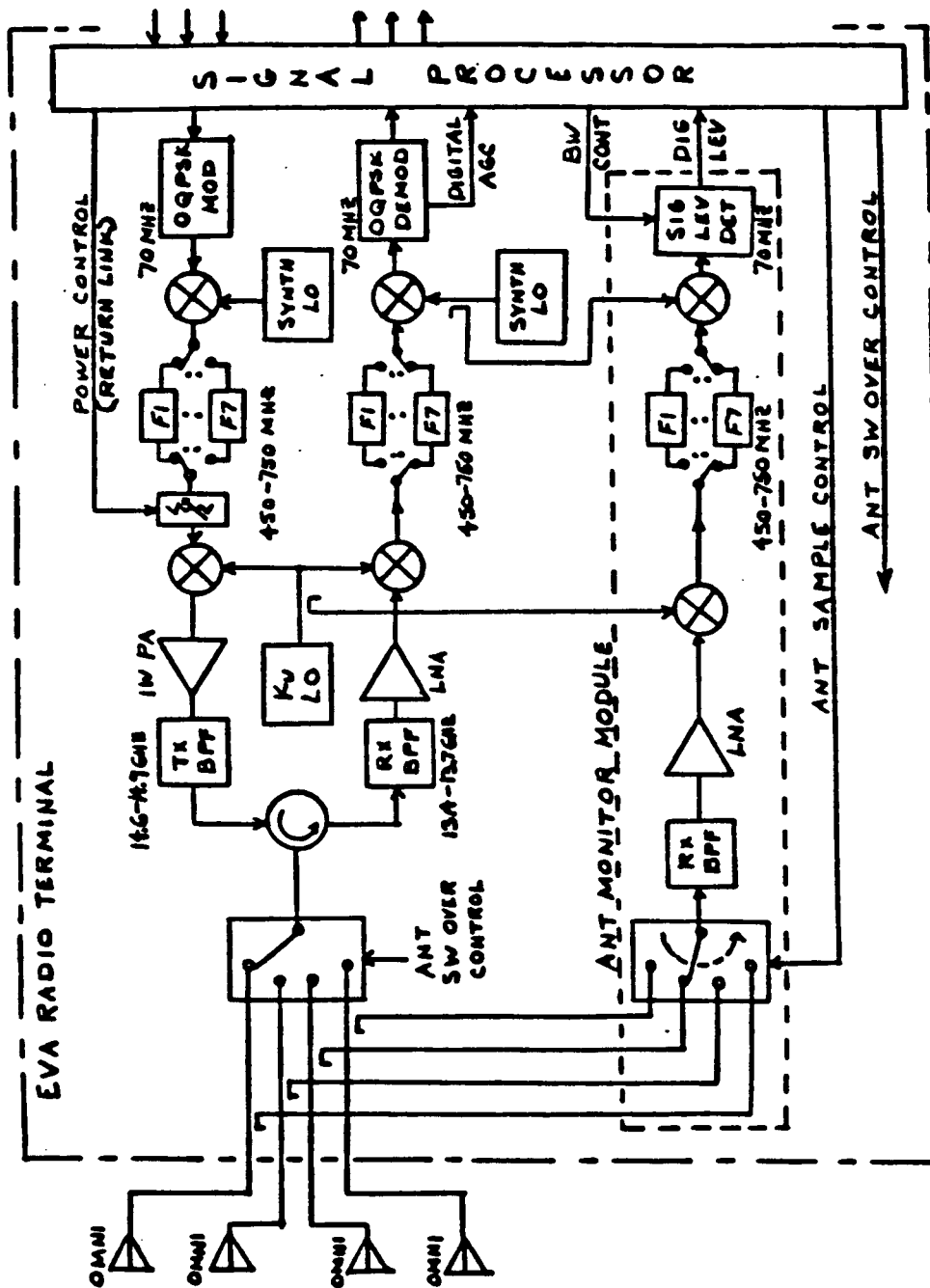
Figure 1. EVA Ku RADIO TERMINAL
ANTENNA SWITCHING CONCEPT

level detector is shown in Figure 2. It consists of a 54 dB
cascaded amplifier, a peak detector, a 25 dB dc amplifier, and an
A/D converter. The circuit for the peak detector - dc Amp. - A/D
converter is shown in Figure 3. The output of the A/D converter is
fed to the signal processor that would be programmed to compare the
strength of the signal samples from various antennas. The signal
processor will then issue a command signal for the single-pole
multi-throw switch and cause it to switch to the antenna with the
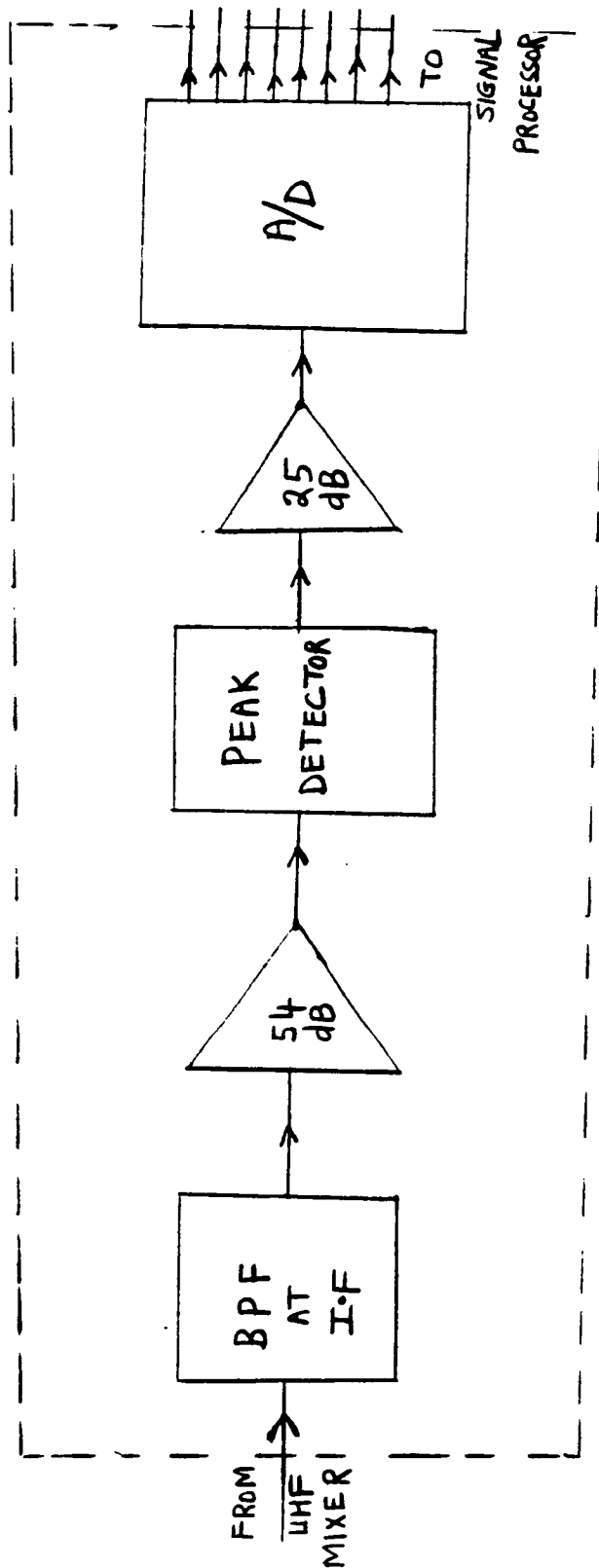largest signal strength.

FROM
UHF
MIXER

BPF
AT
I·F

54
dB

PEAK
DETECTOR

25
dB

A/D

TO
SIGNAL
PROCESSOR
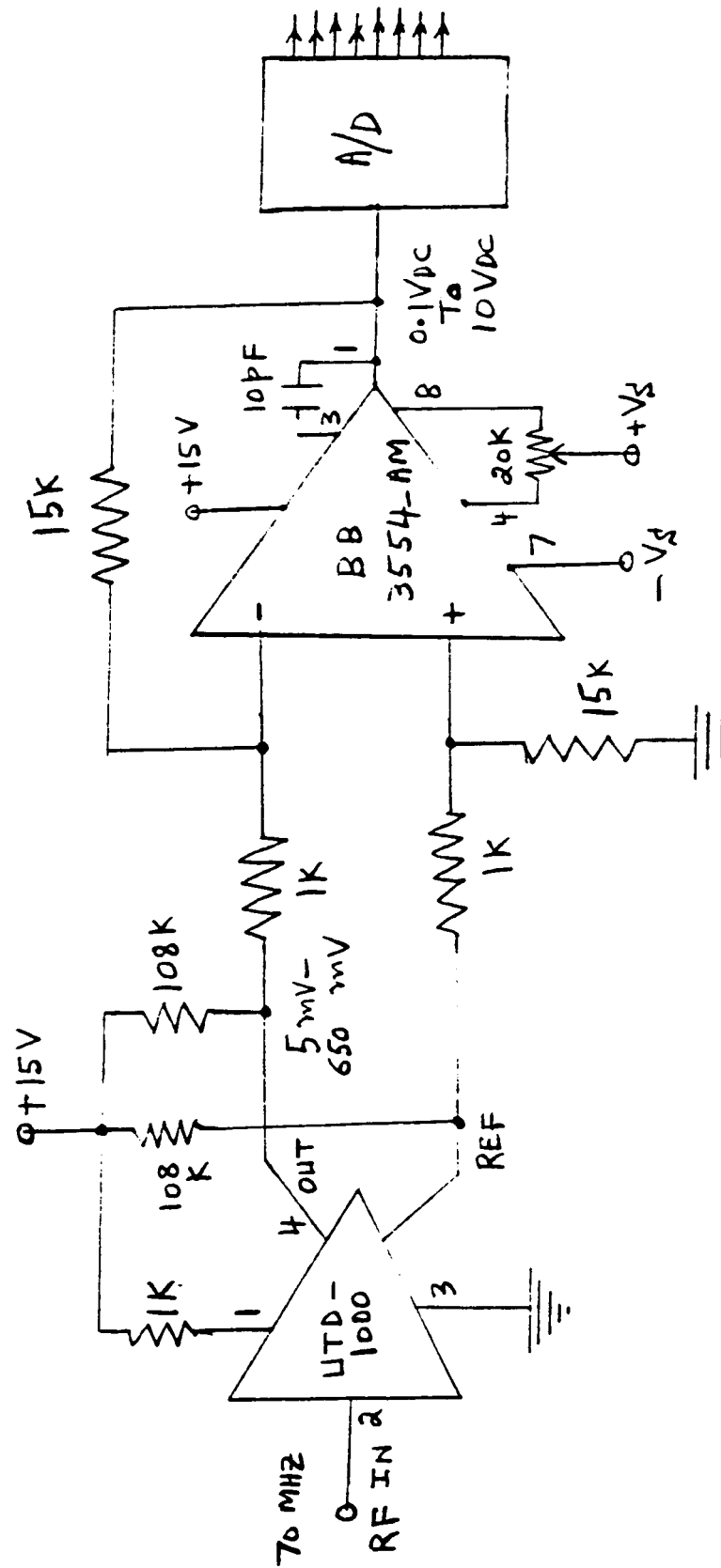
Figure 2.   Signal Level Detector Block Diagram

Figure 3. Peak Detector – Inverting Amp – A/D Converter Circuit

FINDING

The implementation of the design of the automatic antenna switching system required selecting suitable PIN diode switches, designing and testing the signal level detector, selecting the directional couplers and ordering the other needed hardware components. The antenna signal monitoring module of Figure 1 between the sampling switch and signal level detector uses the same type of blocks as the receive module just before the demodulator. The transmit/receive module board for EVA was built by RCA and since an extra board was available, it would be used for monitorong antenna signals. The block diagram of the signal level detector is shown in Figure 2. Its input is the signal from UHF mixer. A brief description of various components in the signal level detector is given below.

Band Pass Filter: To pass the low or high data rate subchannel at 70 MHz with 300 or 600 KHz bandwidth required a band-pass filter. This filter circuit was designed, bread-boarded and tested. The design goals were:

Center Frequency = 70 MHz

Bandwidth = 1.5 MHz

Pass Band Ripple = 0.1 dB

Filter Attenuation < - 15 dB at f>75 Mhz

A Chebyshev design with three LC sections was chosen as it

had steeper roll off and it met the design goals. The filter circuit was synthesized using ESYN program in the EESOF package. The synthesized circuit is shown in Figure 4. A file for a microwave CAD program called TOUCHSTONE was created for the circuit synthesized. The TOUCHSTONE circuit file is shown in Figure 5. The TOUCHSTONE program simulates the circuit and plots the frequency response which is shown in Figure 6 and Figure 7. The circuit response meets the design goals. The filter circuit was optimized by TOUCHSTONE using Monte Carlo analysis to meet the performance goals of:

Pass Band Loss > - 5 dB

Out of Band Loss < - 15 dB at f> 75 MHz

The Monte Carlo analysis indicated that to meet the performance goals, the component tolerance has to be very tight, less than 2 percent. A printed circuit board layout was made using MICAD program. A rubylith mask (1:1) was made using MICMASK program and a printed circuit board was etched in the Lockheed Lab. The components were mounted on the board using split-tip welding and soldering techniques. The circuit was tested using the HP8350B Sweep Oscillator and the HP8757A Scalar Network Analyzer and the desired response was not obtained. Different values were tried for the series inductors and the variable series Giga-trim Capacitors (.5-2.5PF) were tuned so that the series section resonates at 70 MHz. The series inductors that gave close to satisfactory results were 1.5 and 1.6 microhenrys. In the shunt branch, the chip capacitor with
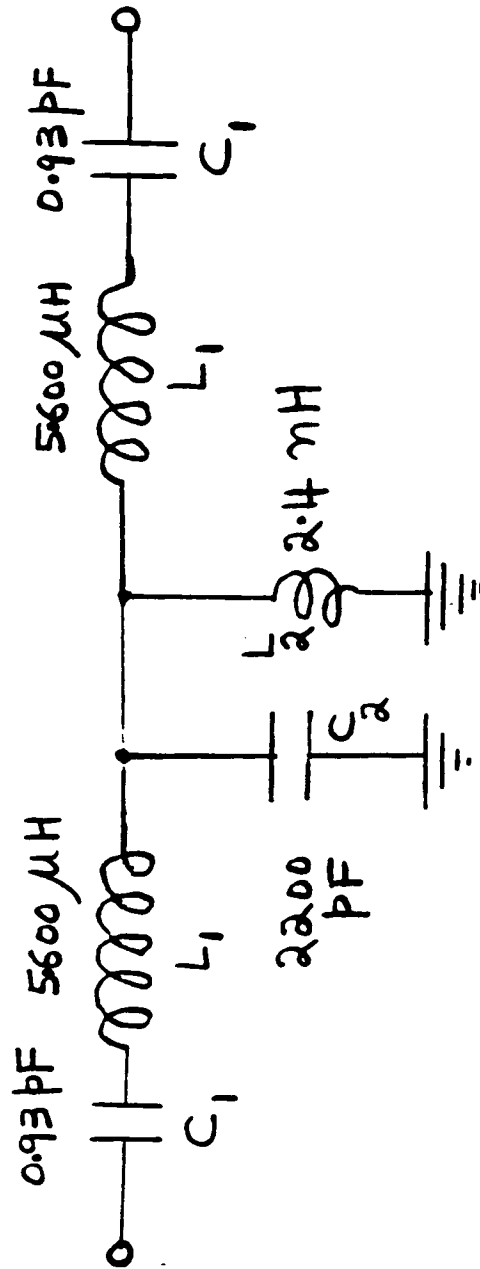
Figure 4. Band Pass Filter Circuit – The Component Values are Close to The Ones Given by ESYN

```
Touchstone (TM) - Configuration( 100 1500 100 16062 1997 1000 1 3294 )
              CB3F70B2.CKT      Tue Jul 28 14:49:39 1987

!  ============================06/30/87 - 10:09:08================================

!                    LUMPED CHEBYSHEV BANDPASS NETWORK
!                    FREQUENCY : 69.00000 to 70.50000 MHz
!      INPUT TERM  : R = 50.00000 Ohms
!      OUTPUT TERM : R = 50.00000 Ohms
!                                      3 RESONATORS
!       0.100000 dB RIPPLE            0.000000 dB MIL          0.000000 dB SLOPE

!  =============================================================================


DIM
    FREQ  MHZ
    RES   OH
    IND   NH
    CAP   PF
    LNG   MIL
    ANG   DEG

CKT
    SLC       1    2   L = 5472.595   C = 0.951500
    PLC       2    0   L = 2.138599   C = 2434.852
    SLC       2    3   L = 5472.595   C = 0.951500
DEF2P         1    3   SYN

    RES       1    0   R = 50.00000
DEF1P         1        R1

    RES       1    0   R = 50.00000
DEF1P         1        R2

OUT
    SYN    DB[S21]    GR1

FREQ
    SWEEP     69.00000   70.50000   0.107143

GRID
    RANGE     69.00000   70.50000   0.150000
    GR1        0.000000  -1.00000   0.100000

TERM
    SYN      R1   R2
```

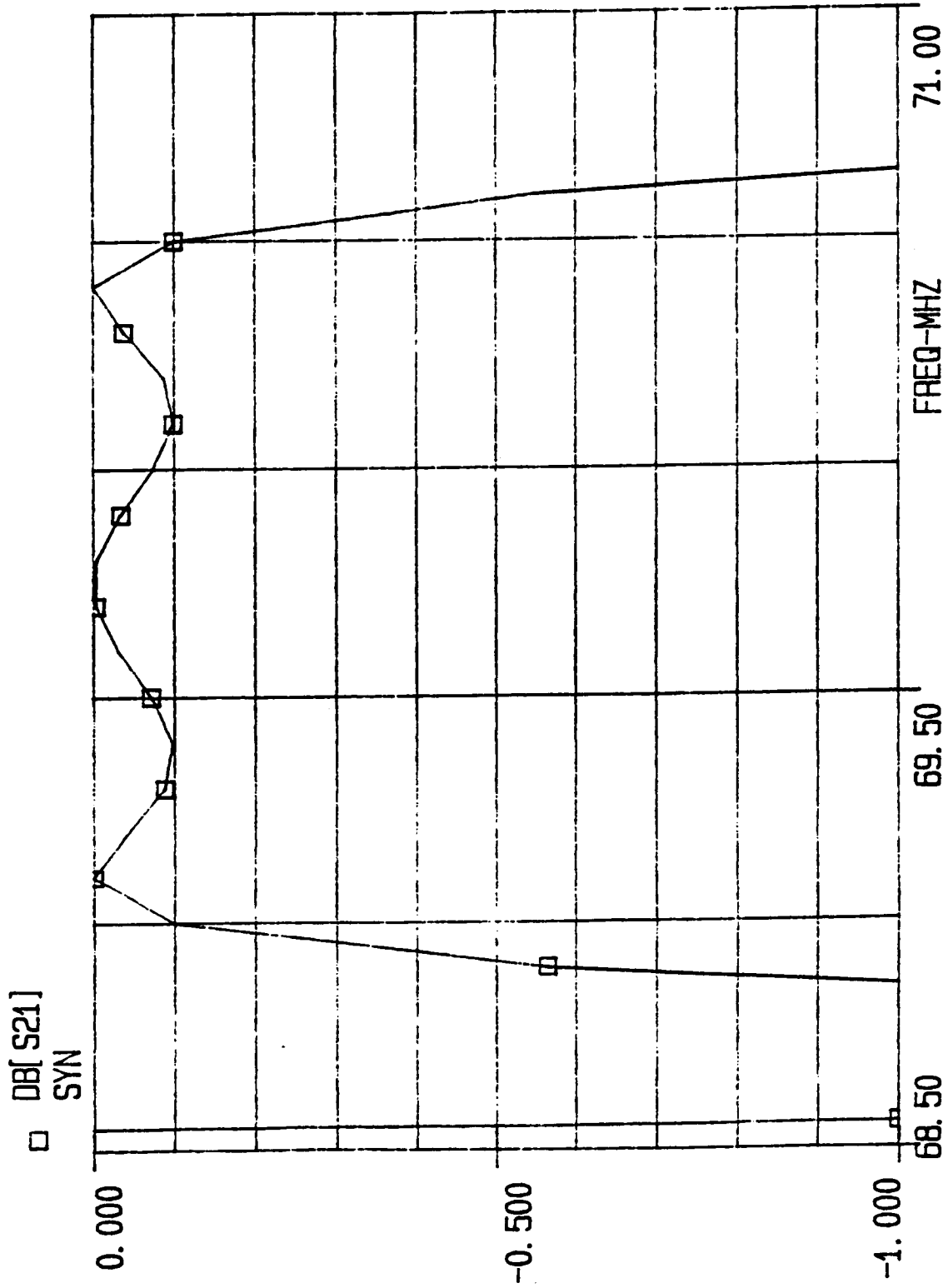Figure 5. TOUCHSTONE Circuit File for BPF

27-12

Figure 6. TOUCHSTONE Plot for BPF

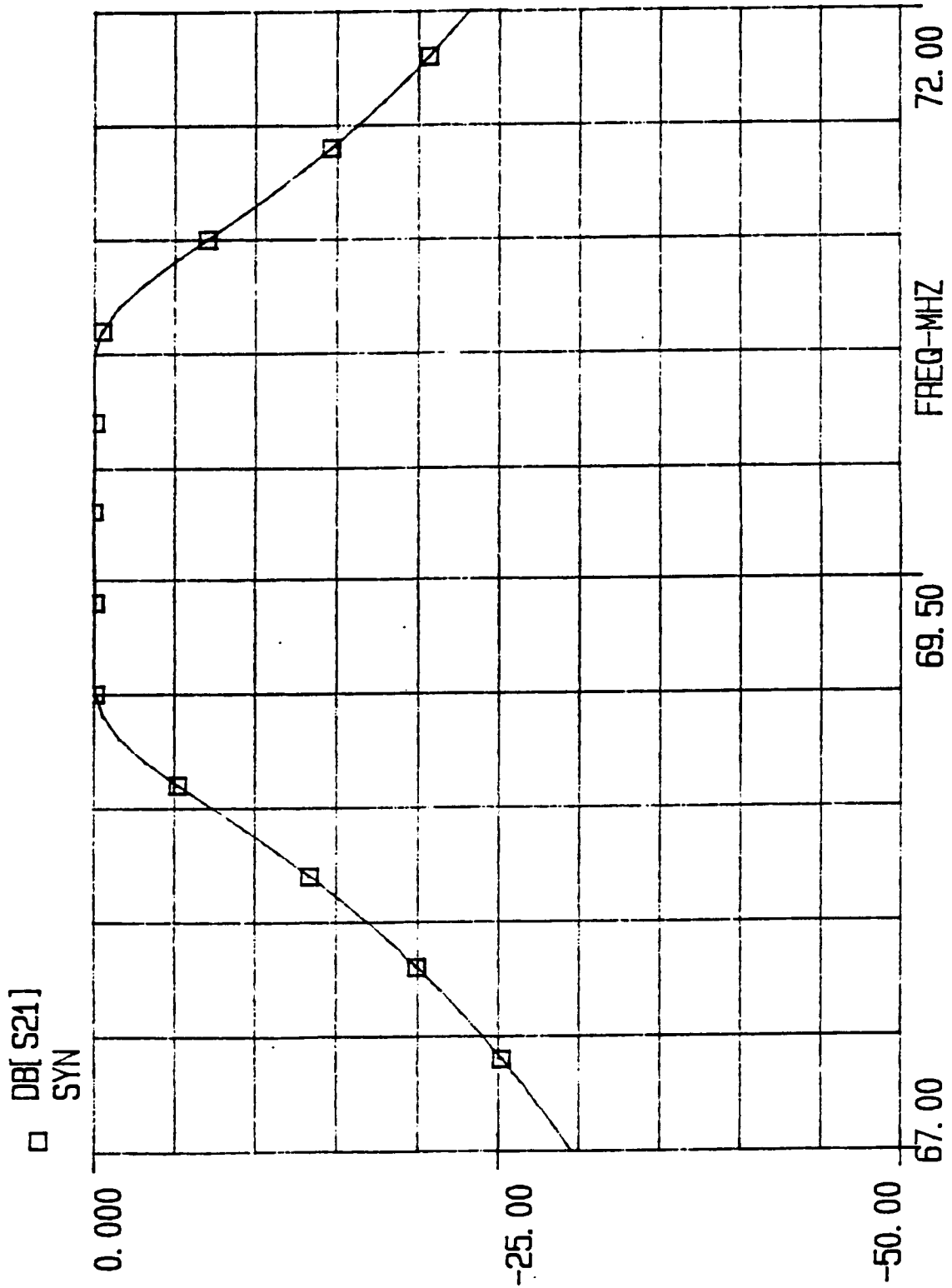EEsof – Touchstone – Tue Jul 28 15:21:53 1987 – CB3F70B2

□ DB[S21]
　　SYN

Figure 7. TOUCHSTONE Filter Plot

1100 PF value was used and the inductor value was about 5 nanohenrys. The frequency response of the filter with its housing and SMA connectors is shown in Figure 8. The return loss appears at channel 1 in Figure 8 and the pass through loss at channel 2. The filter had more insertion loss and wider bandwidth than expected. A part of the problem was getting all sections to resonant at the same frequency and having to deal with a new nanohenry inductor. The filter circuit design given by ESYN gave the starting component values, but the actual values that gave close to satisfactory performance was found by trial and error and they were:

L_1 = 1.50 - 1.59 μH

C_1 = .5 - 2.5 PF

L_2 = 5 NH

C_2 = 1100 PF

Cascaded Amplifier: This is a high gain (54 dB) low noise (NF<2.7 dB) AVANTEK UTC5-213 amplifier. The amplifier was tested using HP Sweep Generator and Scaler Network Analyser and was found to yield a gain of 56 dB with less than 0.5 dB gain flatness in the 50 - 90 MHz range.

Peak Detector: A UTD-1000 level detector was selected as it had an input impedance of 50 ohms. The detector consists of an active high to low impedance converter that drives a Schottky-barrier detector diode. Matched back-to-back silicon diodes which are closely thermally-coupled to the detector provide a dc tracking reference. The output of
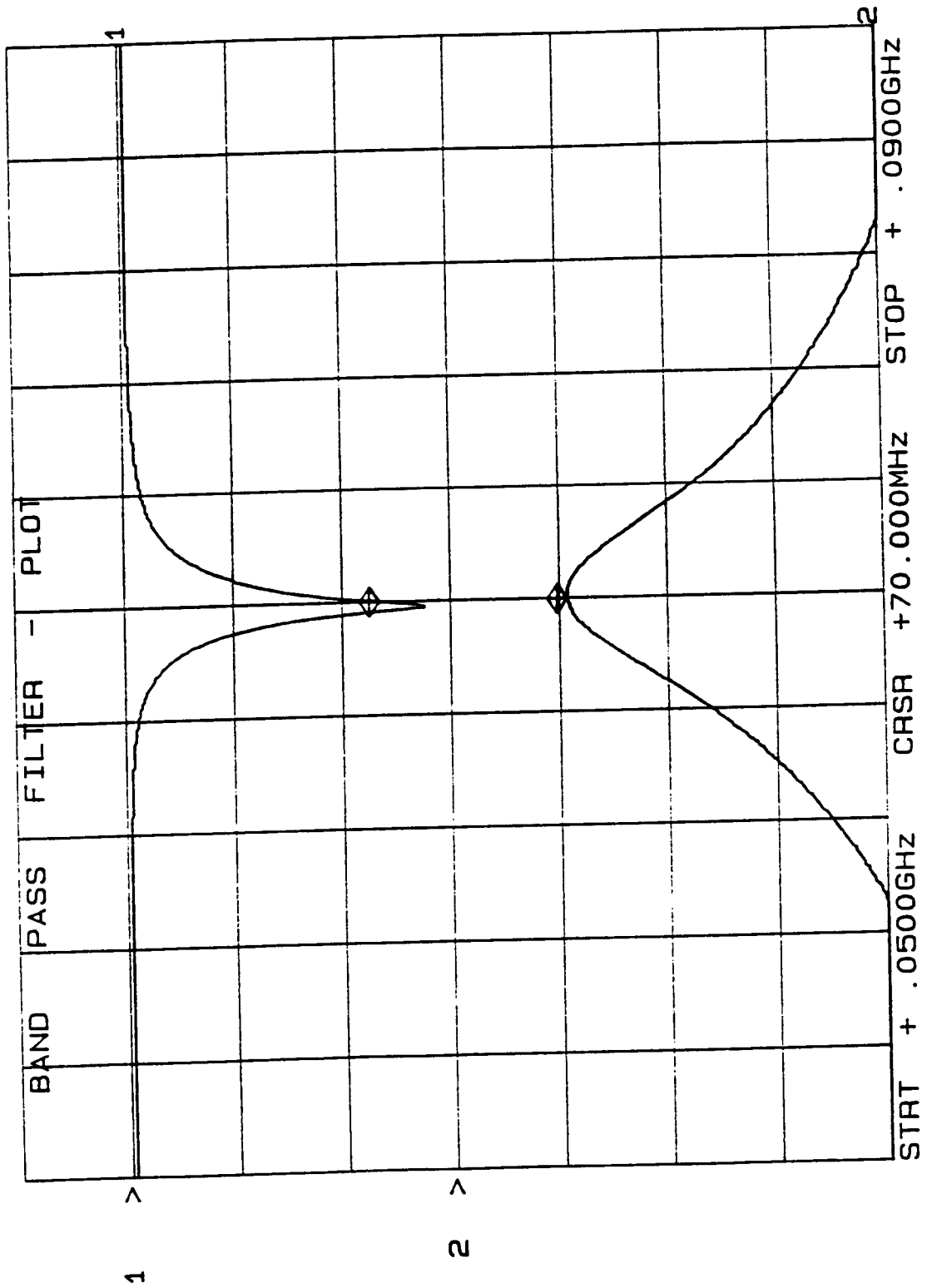
Figure 8. Filter Plot Using HP Scaler Network Analyzer

the detector is a dc voltage that varies in the - 5 mv
to - 650 mv range as the input signal power varies from
- 30 to + 10 dBm. An inverter amplifier with a voltage
gain of 15 is built using an OPAMP 3554, which changes
the output of the peak detector to the range .1 - 10V.
The OPAMP has a high slew rate, a high gain-bandwidth
product and fast settling time. The output of the in-
verter is fed to a very high speed 8 bit resolution A/D
converter that has conversion time less than one micro-
second. The 8 bit digital signal will be applied to a
signal processor. The signal processor will be programmed
to compare the digital signals from different antennas
and issue a control signal to the microwave switch on the
top of Figure 1 that will switch it to the antenna with
the highest signal strength. Mr. John Ngo was assigned the
responsibility to look into the problem of programming
the signal processor to get the above mentioned task
accomplished.

Directional Coupler: Four directional couplers are shown in
Figure 1 placed between antennas and microwave switches.
The ones purchased were 10 dB couplers made by ARRA,
Model #9164-10. They had low insertion loss (<.6 dB)
and high directivity (>25 dB). They were tested on the
Scalar Network Analyzer.

Microwave Switches: Two microwave single-pole multi-throw
diode switches that have low insertion loss and high

isolation between the output ports were ordered. They are
made by Harold Tek and the model # is S2D182-32. Their
delivery is being awaited presently.

Conclusions

The automatic antenna switching design for EVA communication link with Base Station as proposed by RCA was studied. The hardware needed for antenna signal monitoring was selected and ordered. As they arrived, they were tested. The bandpass filter at IF was designed, fabricated, and tested. The peak detector and the inverting amplifier that followed it were breadboarded and tested. Due to the delay in the procurement of the components needed, the assembly of signal level detector could not be completed. A request was made that someone at NASA/JSC be assigned to complete the project, test the switching system design and study the effect of switching on the transmitted data.

Acknowledgements

It is my pleasure to thank my NASA colleagues, Dr. G. D. Arndt and Mr. John Ngo of the Electromagnetic Systems Branch at NASA/JSC for their continued help and support during my summer stay. I would also like to express my thanks to Mr. Roland Shaw and Jeff Kovitz for their help during fabrication and testing of the bandpass filter. My sincere thanks to Margie Robertson for typing this report.