Chapter 4

Miscellaneous

4.1 Sun Noise Measurements

Allen Katz K2UYH - August 1975

Although Sunnoise measurement is certainly accepted as an important measure of EME-station performance, there appears to be some disagreement on the actual mechanics of its measurement. The Sunnoise figure referred to by most stations is a Y factor very similar to the one used in receiver noise figure measurement. It represents the difference in dB between the noise output of the receiver with the antenna pointed at the sun and the noise output with the antenna pointed at a cold (noise wise) portion of the sky. Generally on 432 MHz the sun direction (1975! Ed.) of the antenna is not very critical.

The easiest way to make this measurement is to place a VU meter across the receiver audio output. The type of meter used is not of great importance. The dB scale of a normal VOM in the AC volts position is satisfactory. Different meters will have different dampening factors which can make determining the average value of noise easier, however, the averaged values determined should be approximately the same. (A DC voltmeter with rectifier and appropriate RC time constants can be used also provided the diode acts linearly). When making measurements the receiver should be in the CW position (BFO on) with AVC disactivated. Most errors in Sunnoise measurement are due to receiver non-linearity. The combined gain of Preamps and converter can saturate many receivers. To check receiver linearity place a pad between the converter and receiver when the antenna is pointed at the sun (10 dB is a good value). The VU meter should drop by the same value as the pad. If it does not a linearity problem exists (or the pad is not working in a matched condition; a 10 dB pad is only a 10 dB pad in a 50 ohm system). With the antenna off the sun, the insertion of the pad should also produce a corresponding drop in VU meter reading. If it does not the converter may not have enough gain to override the receiver noise figure. Alternately, the VU meter reading with the antenna of the sun, can be noted. The antenna can then be pointed at the sun and sufficient attenuation (use step attenuator) inserted between converter and receiver to bring the VU meter back to its initial position. The value of the attenuator corresponds to the Sunnoise reading. This approach avoids the problem of receiver non-linearity, but does not insure a correct reading because of the possibility of mismatch between converter and receiver. Ideally both attenuator setting and VU meter reading should be the same.

4.2 Notes on Biological Effects of RF Radiation

Jim Fisk W1DTY - January 1976

Reprint of a letter from W1DTY, editor in chief of Ham-Radio to K2UYH dated October 14, 1975.

Dear All:

Although I didn't have a chance to discuss it with you further at Reston, I gathered from your comments that you were concerned about the power densities in the field of large aperture antennas. First of all, I would like to point out that my conclusion that "10 W input to a 30 Foot dish at 432 MHz is hazardous at distances of less than 18 Feet" is in error. Unfortunately, I don't have a copy of my original calculations, so I don't know where it went wrong, but apparently I made some wrong assumptions. Assuming a 30 Foot dish at 432 MHz, approximately 1642 W into the antenna would be required for a power density of $10 mW/cm^2$ in the near field (extends about 156 Feet for the 30 Foot dish at 432).

Although the maximum power density is usually in the near field, the wave formation here is highly complex and the mathematics are beyond most amateurs. However, in most cases it appears that the launched aperture distribution continues to a distance of about that of the largest antenna dimension. This is implied in the work of Dr. Rudduck of Ohio States, but involves Hankel, Bessel and Fresnel functions as well as his steepest descents approach to plane wave spectrum formulation.

For the practical work, however, the near field of a parabolic antenna can be considered to extend out from the antenna to a distance of A/λ where A is the area of the antenna aperture (ITT's Reference Data for Radio Engineers, fifth edition, page 23-47). For a 30 Foot dish at 432 MHz this is 47.6 meters or about 156 Feet. Furthermore, the maximum power density in the near field is equal to approximately 4P/A where P is the average power into the antenna and A is the antenna area. Although this maximum power density occurs at a distance of about $0.2D^2$ from the antenna (D = antenna diameter), it is apparently usual practice when considering radiation hazards to assume that the power density on the antenna axis is at its maximum value throughout the length of the near-field region.

Using this as a basis, tabulated below are the maximum power densities in the near field vs power input for a 30 Foot dish:

Power Input	**Power Density**
10W	$0.061\ mW/cm^2$
164W	$1.0\ mW/cm^2$
500W	$3.0\ mW/cm^2$
1000W	$6.1\ mW/cm^2$
1642W	$10.0\ mW/cm^2$

It would appear that even with 1000 Watts into the antenna a person could stand in the main axis for a pretty long period of time without any undue effects. For frequencies above 200 MHz the Air Force uses the following time equation to define the maximum allowable power density in terms of exposure time:

$$Pd \leq SQR(6600/T) mW/cm^2$$

Where Pd is the power density and T is greater than 2 minutes and less than 60 minutes ($2 \leq T \leq 60$ minutes). That is, power density cannot exceed $55 mW/cm^2$ (2 minutes exposure), and when T exceeds 60 minutes the maximum permissible level is OSHA's $10 mW/cm^2$.

Although the power density in the far field and the transition region is not a problem at amateur power levels, as a matter of interest the far field region is usually considered to begin at a distance $2D^2/\lambda$ from the antenna (about five times the length of the near-field region, or about 242 meters (794 Feet) for a 30 Foot dish at 432 MHz. The approximate maximum power density at this distance (on the antenna axis) is given by $P/5.1D^2$ and a quick calculation will reveal that an average power input of about 4264 W would be required to reach a power density of 1 mW/cm^2 on the antenna axis at the beginning of the far field. As might be guessed, the transition region doesn't cause any problems either because the maximum power density decreases approximately as the square of the distance from the outer limit of the near field region.

I presume that multiple element arrays could be evaluated on somewhat the same basis, but since a 30 Foot dish represents the upper limit for amateur antennas (except for K2CBA), there's apparently little hazard at amateur power levels. Note that the power density equation in the near field does not include a wavelength factor so the same numbers would apply at all amateur frequencies -the rear field is simply longer at higher frequencies and shorter at lower ones. However, since power density is laversaly proportional to the area of the parabolic reflector, smaller dishes actually provide higher power densities in the near field. A 2.5 Foot dish for example, will provide power densities in the near field of about 10mW/cm^2, along with the length of the near field at 432 MHz:

Dish diameter	**Input for 10mW/cm^2**	**Length of Near Field**
30 ft	1642 W	156 ft
20 ft	730 W	69 ft
15 ft	410 W	39 ft
10 ft	182 W	17 ft
5 ft	46 W	5 ft
2 ft	7 W	8 inch

The last case would probably be approximately true for single boom Yagis as well. Obviously the subject needs a good deal more study, but until some conclusive results have been obtained, all VHF operators should use caution.

I suspect that amateurs are much more likely to be exposed to high RF radiation fields when they are working on their rigs than they are when standing in front of their antennas. A power amplifier cover that is not tightly sealed, for example, may act as a slot radiator, resulting in some rather higher power densities near the chassis.

Best Regards, Jim Fisk W1DTY

4.3 Equations for Geometric Moon Polarisation Rotation

Walt Bohlman K3BPP - November 1976

As a result of earth moon earth geometry, even when there is no Faraday rotation present, you may still have to use a polarisation other than horizontal when trying to work another horizontal-polarised station. This geometric polarisation rotation, which is always the same for transmit and receive, can many times be estimated by visualising the reflecting action of the moon in relation to the position of the antennas involved. Sometimes the amount of geometric rotation is not obvious. Walt, K3BPP of the W3CCX group has developed the following equation for calculating the geometric rotation angle:

$$PolarisationAngle = ArcTan\left\{\frac{sub1}{sub2 - sub3}\right\}$$

$$sub1 = [sin\theta_2 cos\theta_1 - sin\theta_1 cos\theta_2 cos(\phi_2 - \phi_1)]sin\alpha_1 - [(cos\theta_2 sin(\phi_2 - \phi_1))cos\alpha_1]$$

$$sub2 = [sin\theta_1 sin\theta_2 + cos\theta_1 cos\theta_2 cos(\phi_2 - \phi_1)]cos\beta_1$$

$$sub3 = [sin\theta_2 cos\theta_1 - sin\theta_1 cos\theta_2 cos(\phi_2 - \phi_1)]cos\alpha_1 sin\beta_1 - [cos\theta_2 sin(\phi_2 - \phi_1)sin\alpha_1 sin\beta_1]$$

Where:

θ_1 = Latitude of your station.
θ_2 = Latitude of remote station.
ϕ_1 = Longitude of your station.
ϕ_2 = Longitude of remote station.
α_1 = Azimuth angle of moon at your station.
β_1 = Elevation angle of moon at your station.

Note:

1. Longitude east of Green which is negative.
2. Polarisation angle is clockwise rotation when looking at the moon.

Although this equation appears rather complex it can be easily evaluated with a programmable calculator or a computer. Walt suggests using the equation to calculate change in polarisation angle with time (for a given day) with a particular area of the world - for example the centre of Europe. There will be little error in polarisation calculated for use with stations located almost anywhere on the continent. Other data however, must be calculated for use with stations in Australia, Japan etc. Once the correct polarisation setting is known (i.e. angle with no Faraday rotation present) a station with rotatable polarisation can peak his polarisation angle on receive and note the change (from the calculated position) but in the opposite direction. Provide that the station at the other end has not rotated his polarisation, this procedure should yield the correct transmit polarisation angle.

4.4 Notes on LDE Reception

John Yurek K3PGP - July 1977

In previous letters we have reported on the reception of multiple echoes by K3PGP. In Figure 4–1 is a chart recording of a second echo received by him. The chart runs from right to left. The receiver had a narrow band audio filter and was tuned to the LDE frequency thus suppressing any first echo. (Despite the April 1 date this is a legitimate report!) John has also been experimenting with the reception of commercial TV carriers off the moon. Listening for echoes as the moon passes through a station's narrow on the horizon beam. He has successfully received a number of U.S. UHF TV carriers using this technique.

4.5 Computer Routine for Geometric Polarisation Rotation

Allen Katz K2UYH - June 1980

I5MSH has caught a bug in the geometric polarisation program I supplied to him several months ago. A corrected version of the subroutine with the changes underlined is shown in Figure 4–2. This subroutine can be integrated into any of the popular moon tracking programs. LA is the latitude and LO the longitude of your station. PA is the latitude and PO is the longitude of the station (or location) to be worked. AZ is the azimuth angle and EL is the elevation angle of the moon at your location at the time of interest. PR is the polarisation rotation angle if no Faraday rotation is present (EL-AZ mount to EL-AZ mount). Plus angle is clockwise when looking at the moon.

Figure 4–1: Long Delayed Echoes Recording

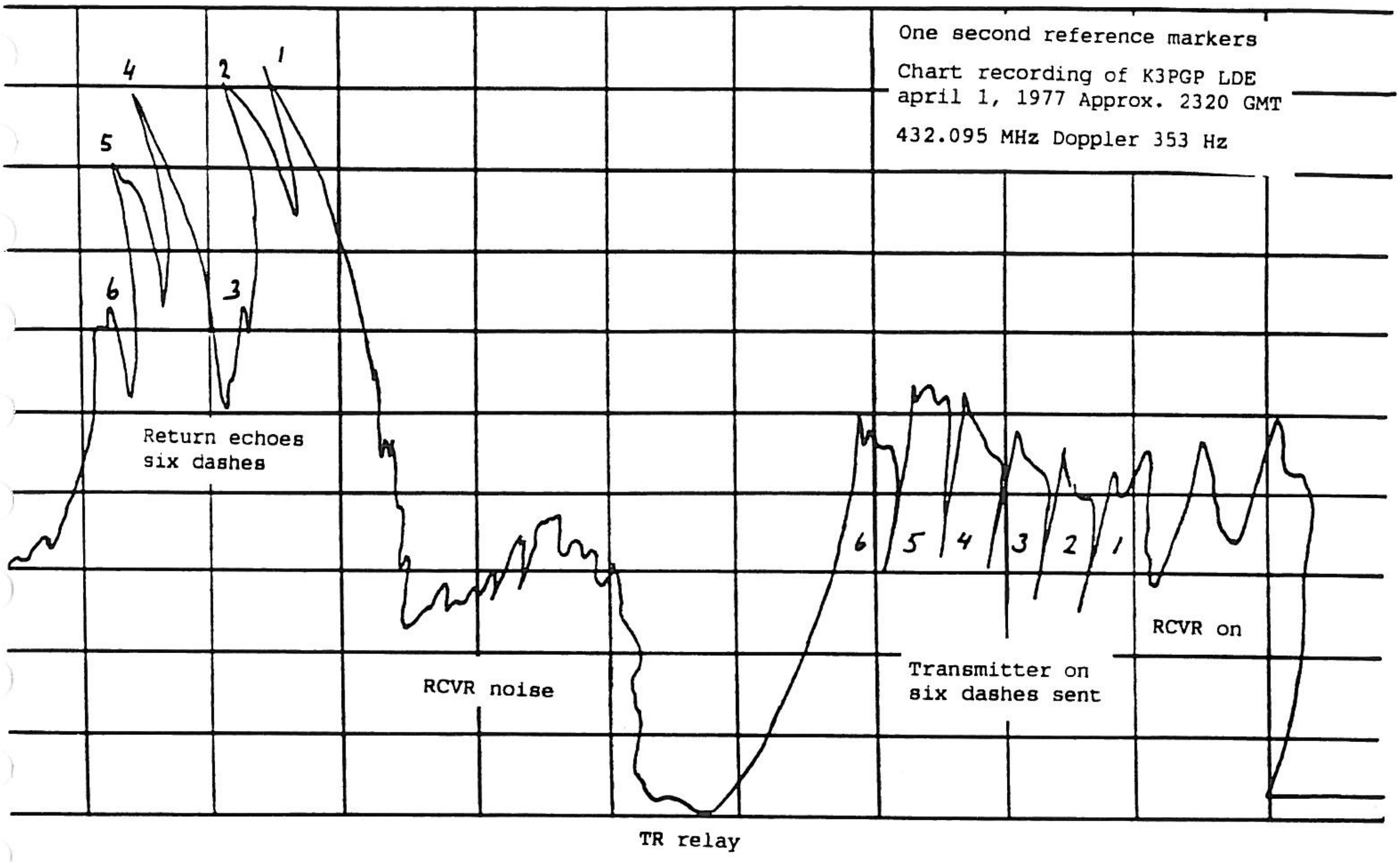

Figure 4–2: Routine for Geometric Polarisation

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1570 TA=(SIN(PA)*COS(LA)-SIN(LA)*COS(PA)*COS(PO-LO))
1580 T2=((COS(PA)*SIN(LO-PO))*COS(AZ))
1590 L1=(SIN(LA)*SIN(PA)+COS(LA)*COS(PA)*COS(PO-LO))
1600 L2=(SIN(PA)*COS(LA)-SIN(LA)*COS(PA)*COS(PO-LO))
1610 L3=(COS(PA)*SIN(LO-PO)*SIN(AZ)*SIN(EL))
1620 PX=(TA*SIN(AZ)-T2)/(L1*COS(EL)-L2*COS(AZ)*SIN(EL)-L3)

1630 PR=ATN(PX)

1640 RETURN
```

4.6 Digital Dish Position Encoding System

John Yurek K3PGP · November 1980

Interest in digital readout of antenna position is growing. I have several technical items relating to this area. Unfortunately the diagrams supplied are too spread out for reproduction in the Newsletter. Digital readout systems can take a number of forms. Angular position can be directly converted into parallel digital information. This is usually accomplished by means of a transparent disk on which a pattern has been printed. Light is sent through the disk and detected by a number of photo sensitive cells. As the disk rotates the pattern changes and the number of activated cells changes. The position of the disk can thus be related to cell pattern. Usually a Gray-code pattern (which changes only one bit or cell at a time) is used. The precision of this system is directly related to the number of cells and corresponding pattern changes. For 1° at least 9 cells corresponding to 512 pattern sectors must be used. The 9 cell outputs can be sent over 9 parallel wires plus ground to the appropriate decoding logic and led display.

The use of 10 or more parallel lines can be inconvenient. Many systems of this type convert the parallel digital data to a serial code using a parallel in, serial out shift register or UART chip. The serial data can be transmitted over two lines to the display unit where it is converted back to parallel form. This is the approach taken by K3PGP for control of his dish. ZE5JJ is using a similar technique, but instead of converting the parallel data to a serial data word he sends a train of pulses which is counted at the display end in a fashion similar to a frequency counter.

4.7 PET Computer Dish Control Interface

Stuart Jones GW3XYW - December 1980

GWXYW is using his PET computer to aim his dish to the moon. He build an interface which connects to the PET User & IEEE port to control his rotaters. Figure 4–3 shows the interface in detail.

4.8 High Power Directional Couplers for 432 and 1296 MHz

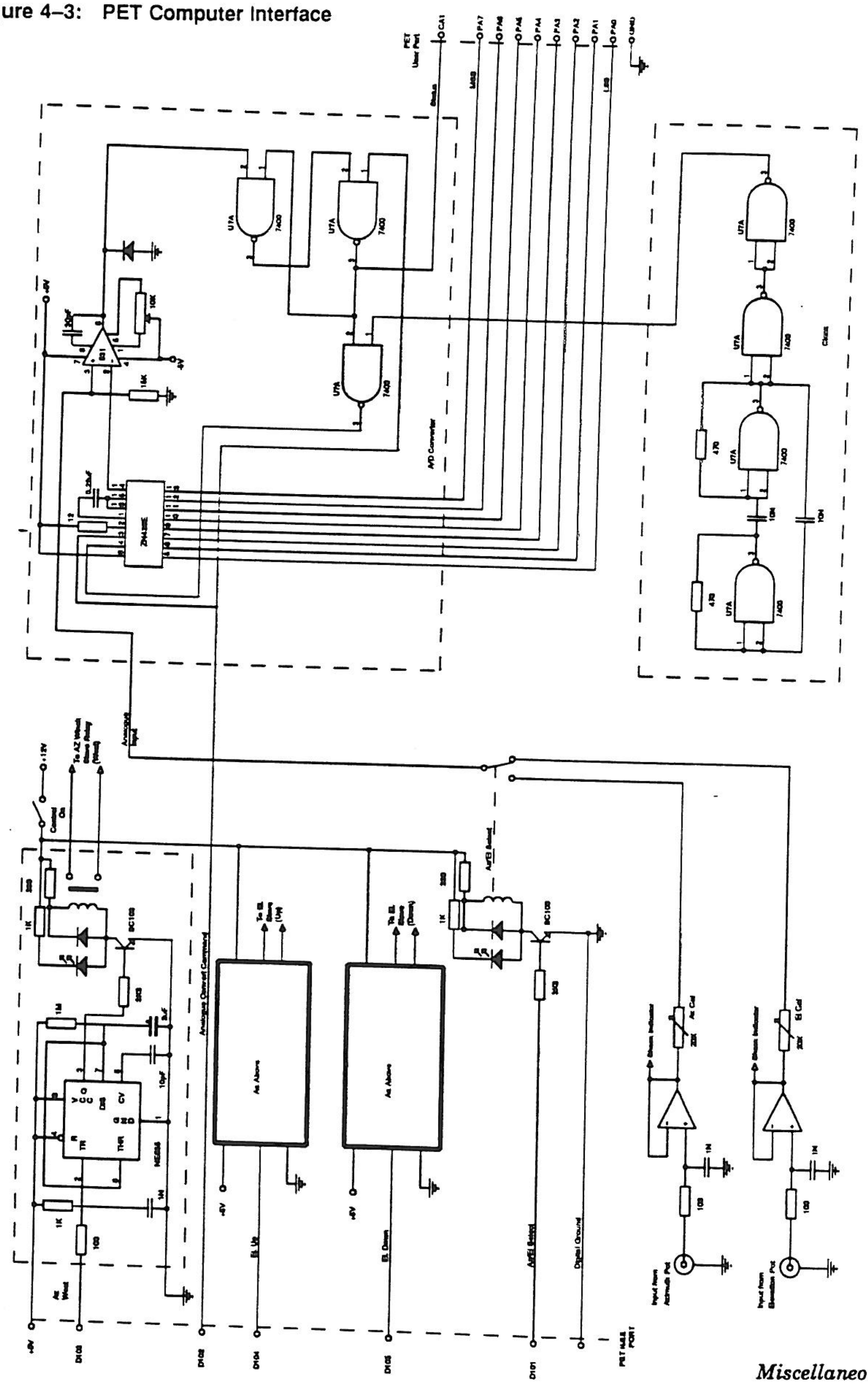
University of Goteborg SK6AB (SM6AOM & SM6ECR) - March 1981

Are you discontent with tying up your BIRD or similar wattmeter for monitoring the output of the power amplifier of your station? Here is an efficient and simple way to build a high power directional coupler. What you need is a length of 3.6 mm semi-rigid coax, a 47 ohm 1/4 W resistor, two pieces of copper or brass tubing and coax connectors of course. The outer diameter of the centre conductor d, and the inner diameter of the outer conductor D, should equate as:

$$Zo = 50 = 138 \cdot log\frac{D}{d}$$

The slot in the outer conductor can be made by drilling a few holes in line with the slot, as close to each other as possible. Then enlarge the hole with a file, so you can pass a small hacksaw blade through the hole. Next, cut two parallel cuts along the full length of the slot. Lastly, smooth both edges of the slot with a file and remove all burrs. This work can of course be simplified if you have access to a milling machine. The semi-rigid coax should than be filed for a length equal to the slot length. The outer jacket is filed away and the Teflon dielectric is exposed to width of about 2.2 mm. Then solder the coax in place as is shown in section A-A. The exposed dielectric should of course face the slot.

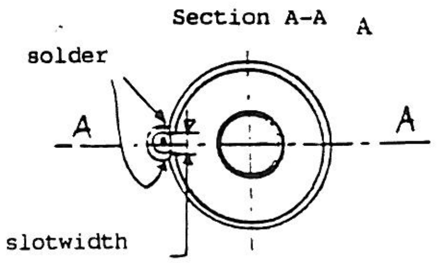
Figure 4–3: PET Computer Interface

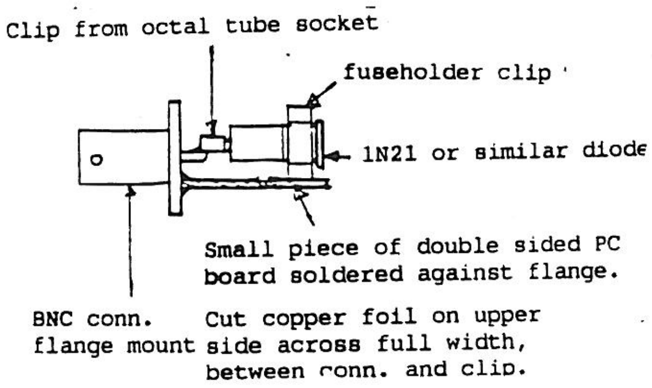


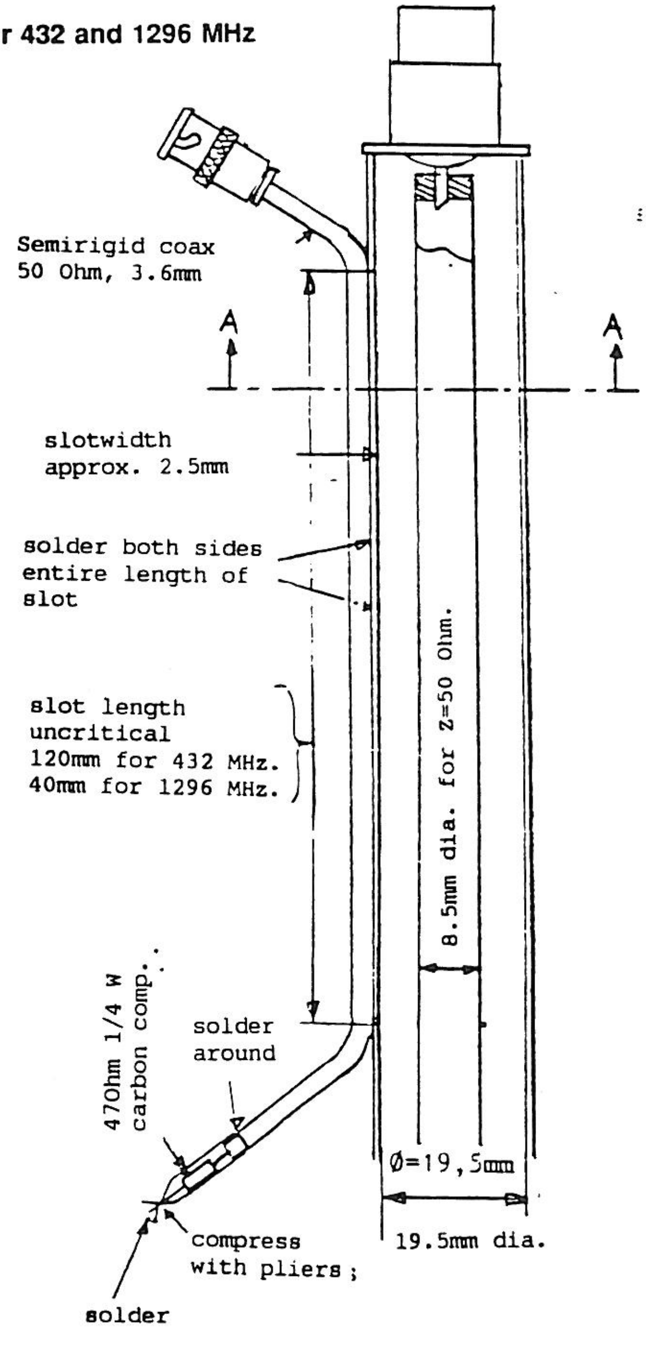
The next step is to install the termination resistor. Prepare both ends of the coax as for BNC connectors. Solder the resistor to the centre conductor with the shortest possible wire. Trim the joint so no solder protrudes outside the dielectric. A piece of copper jacket is then slipped over the resistor and soldered against the end of the outer jacket. Finally compress the other end of the jacket piece against the resistor wire, and solder. Be careful not to break the resistor. The other end of the coax is equipped with a coax connector in a conventional manner. What is left, is to install the centre conductor and the connectors in the main line. Be careful to install it exactly concentrical.

The indicator for the coupler can be an RF-power meter, an RF voltmeter with termination or a diode probe with moving coil meter. A diode detector can be constructed as the figure below. Not shown in the drawing is a terminating resistor connected between earth and the centre pin of the connector, and a decoupling capacitor. Also a series calibration resistor for the meter is needed. Calibration of the coupler can be accomplished with a receiver and a calibrated attenuator + a signal generator, or by comparison with a Bird or similar wattmeter. Our coupler was measured with a HP-8553B spectrum analyser with a tracking generator. The results were: on 432, coupling -56 dB directivity 28 dB and on 1296, -62 dB and 18 dB, respectively. A smaller diameter mainline and the coupling line deeper in the slot gives higher coupling. If you make a dual coupler, you can monitor forward and reflected power at the same time, which is very convenient.

Figure 4–4: High Power Directional Couplers for 432 and 1296 MHz







4.9 Power Dividers from Coax Adapters

Dick Turrin W2IMU - April 1981

Sometimes excellent ideas are forgotten. A recent letter reminded me of the technical note originally written by W2IMU almost 10 years ago which is reprinted below. This note describes low-loss power dividers which can be used to stack 432 and 1296 Yagis. These combiners are composed of nothing more than a collection of coaxial adapters (mainly Tees) and perform very well. They work on the principle that when two 50 ohm loads are connected in parallel the result is a 25 ohm load. This load will be transformed to a 100 ohm load by a quarter wave length of 50 ohm coax. Connecting two of these 100 ohm loads in parallel brings the impedance back to 50 ohm. Thus only 50 ohm line (or 50 ohm adapters) need to be used to connect four 50 ohm antennas together. The secret is to get the right length for a quarter wavelength and this is what the note tells you. For this reason the adapters specified should be used. (Although there are other adapter combinations which will yield similar results).

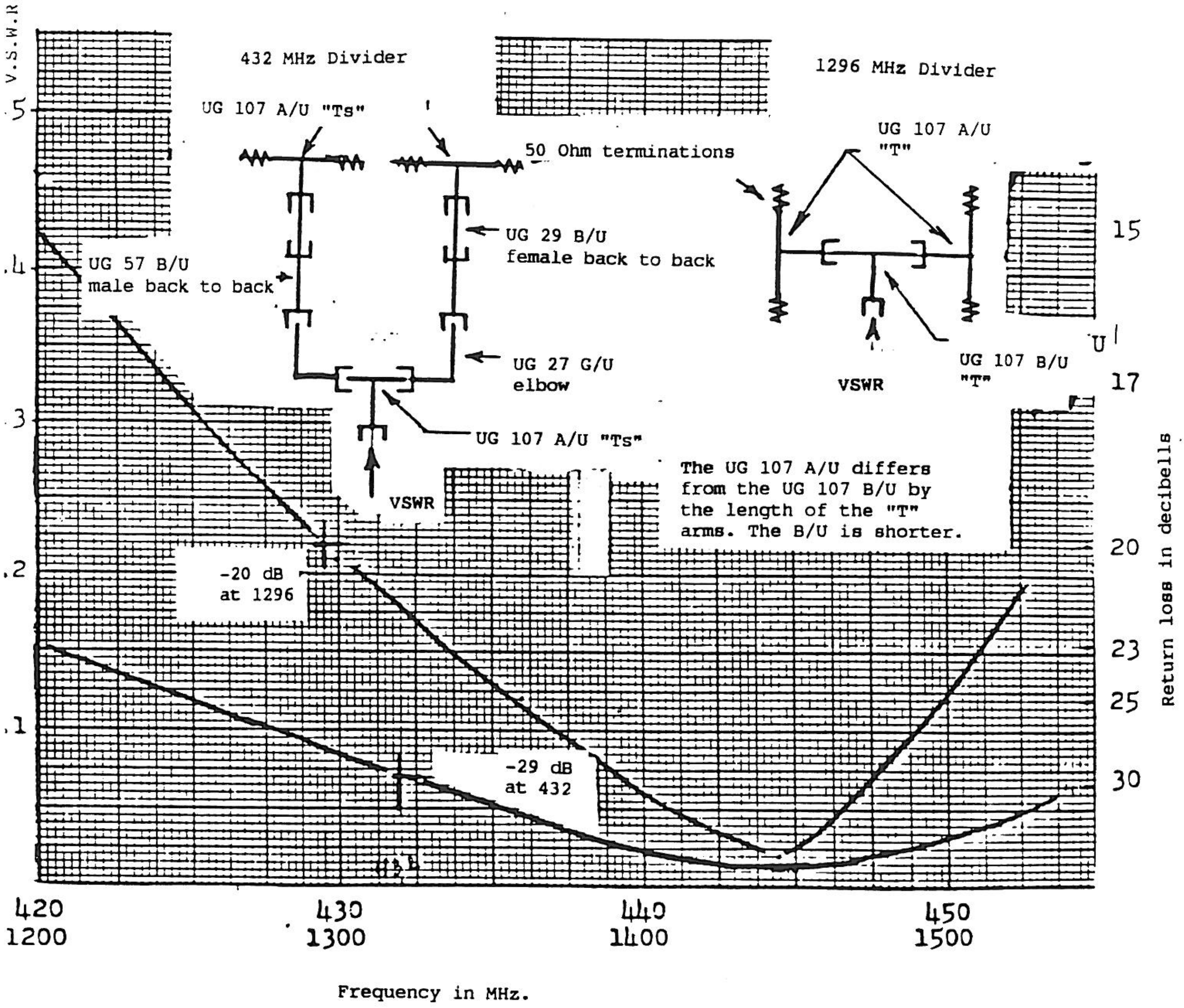
From: The Crawford Hill VHF-club date: December 1971
Subject: UHF Power Dividers

Presented in this report are two 50 ohm 4-way power dividers of the reactive type composed entirely of standard type "N" fittings. One of the dividers is for 432 MHz and the other for 1296 MHz. These power dividers are particular useful for feeding four identical antennas in an in phase array.

Below are shown the design of each divider and the required type of "N" fittings for each. The curves are the measured VSWR at the common port for each divider. Note that each divider has a natural best match frequency which is slightly higher than the desired operating frequency.

The 432 MHz divider was developed by W2CCY and the 1296 MHz divider by W2CQH.

Figure 4–5: Power Dividers from Coax



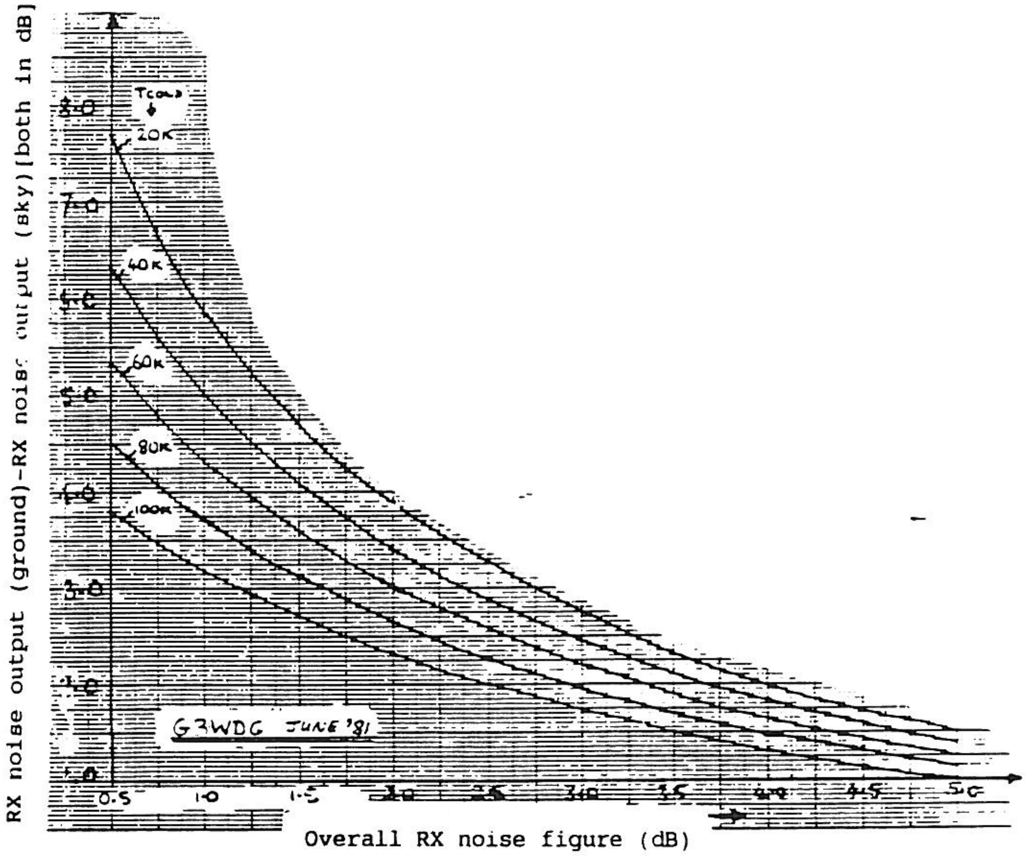
4.10 Cold Sky Ground Noise Curves

Charles Suckling G3WDG - July 1981

With the very low noise Preamps available today, system noise temperature is becoming almost as important a system parameter as gain. Some stations using Yagis have changed over to open wire feedline to lower system noise. (Those of us using dishes should check the performance of our feed antennas for noise contribution as well as gain). The chart provides a means for determining system noise temperature. It also can be used to verify receiver noise figure when the system noise temperature is known.

The Graph in Figure 4–6 shows difference in RX noise outputs (in dB) with antenna pointing at ground and at cold sky, as a function of RX noise figure. Below about 1 GHz, accuracy may be reduced due to ground reflections of cold sky! Various "cold" antenna temperatures are given. For example a dual mode feed horn at 1296 is about 20°K, a 0.6 f/D dish at 1296 is about 50-60 K and a 0.6 f/D dish at 432 is around 80°K. Always have the RX AGC off during measurements, ensure that antenna is clear of any local buildings, trees etc. For ground measurement, point antenna sufficiently below horizon to get max. noise. With horn and other dish feeds, do not hold antenna close to ground, or VSWR may change enough to affect RX noise output and ruin measurement accuracy.

Figure 4–6: Cold Sky Ground Noise Curves



4.11 Transistor Diode Noise Source

Allen Katz K2UYH - August 1981

There has been a number of requests recently for information on diode noise sources. A source can be easily made from the emitter-base junction of most high F small signal devices (MRF901 etc) as shown in the following figure. The old KMC KD55 works very well in this circuit). The values of R, C and +V are not critical and can be varied to obtain a high noise level at a point which is not voltage sensitive. Commercial sources adjust R and C for a flat noise versus frequency response. For hams who are interested in the noise level at a particular frequency band, frequency response is not an important consideration. The attenuator value should be greater than 10 dB to ensure a good match. The higher the attenuation the better the match, but the lower the level of excess noise (Xn).

Calibration can be a problem. The noise source can be used without calibration for relative measurements. However for EME most of us want to know actual values. The easiest way to calibrate a noise source is to measure the Y factor (YF) of a known NF amplifier - just as if you were performing a NF measurement. The noise figure of a device is given by the following formula:

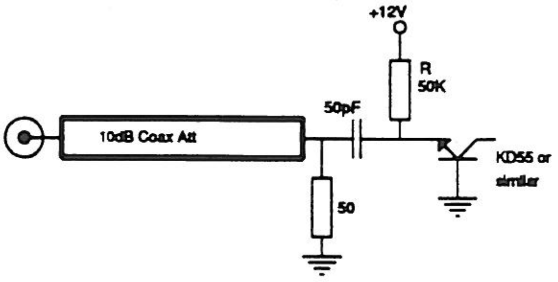
$$NF(dB) = Xn(dB) - 10Log(\frac{YF/10}{10-1})$$

where Xn is the excess noise of the source. If the noise figure is known, the equation can be turned around to provide the unknown Xn of the source in terms of YF.

$$Xn(dB) = NF(dB) + 10Log(\frac{YF/10}{10-1})$$

If an additional attenuator is used in front of the noise source, the Xn is the original Xn minus the value of the attenuator. Calibration must be performed for each band of interest and can yield good NF measures if performed with care.

Figure 4–7: K2UYH Noise Source



4.12 EME RST Signal Report

Allen Katz K2UYH - September 1981

Readability: 1 - unreadable (copy < 5%)
2 - barely readable (5% < copy <25%)
3 - readable with consid. dif. (25% < copy <75%)
4 - readable with pract. no dif. (75% < copy <95%)
5 - perfectly readable (copy > 95%)

Strength: 1 - barely perceptible
2 - very weak
3 - weak
4 - fair
5 - good
6 - very good

4.13 Sun Tracking Program

Bryan Rambo WB4WMT - December 1981

Since last month I have received two Sun-tracking programs. One from Bryan WB4WMT and another from W4WD. The one shown in Figure 4–8 is from WB4WMT and is the shorter of the two. I have personally tried this program and can verify its performance. The program is written to run in Microsoft disk BASIC, but will also work with 8K BASIC. One problem I had is, that the program uses variable names longer than 2 characters in length. I had to shorten all names to two, but my BASIC is not from Microsoft. The program gives four options:

GO > Display next hour.
NHR > Go to a different hour.
NDAY > Go to a new day.
Quit > Return to basic command level.

The program rounds all output to the nearest degree, those wishing greater precision can modify statement 70. I may also run the other program in the near future which produces the Sun data in a format identical to the common moon track programs.

4.14 Improving 70 cm EME Operating Procedure

Joe Reisert W1JR - February 1982

70 CM EME has now matured and many QSO's are somewhat routine. This wasn't true 10 years ago. The principal reasons are improvements in antennas, power amplifiers, receivers and operating procedures. We have now developed antennas that have high gain and some are quite large! 1000 W Power Amplifiers using various tubes and circuitry are available. Preamplifiers using relatively inexpensive GaAsFets are almost as quiet as the sky behind our antennas. However, some of our operating procedures could still use improvements to further increase our QSO rates.

Let's talk a moment on operating procedures. A valid QSO consists of an exchange of calls, signal reports and R's. On HF the RST system has long been used as the signal report. Signals can be quite strong and it usually isn't difficult to copy a 229 report if the QRM doesn't get you. However, on EME the signals are seldom strong (except from the very large stations). Add to this the non-reciprocity of Faraday rotation and liberation fading and you have a situation were everything must be just right for a QSO. Realising this the TMO code (in its various forms) was developed in the 60's by EME operators

Figure 4–8: WB4WMT's Sun tracking program

```
10 REM sun tracking program by Bryan Rambo
20 REM written in microsoft basic ver 5.2
30 REM screen oriented for box 20 dumb terminal
40 TWOPI=6.28319: RPD=TWOPI/360
50 DEF FNS(X)=ATN(X/SQR(1-X*X))
60 DEF FNC(X)=TWOPI/4-ATN(X/SQR(X*X))
70 DEF FNI(X)=INT(.5+X)
80 DEF FNR(X)=X-TWOPI*INT(X/TWOPI)
90 PRINT "Enter Callsign": INPUT CAL$
100 PRINT "Enter longitude and lattitude --Example-- 84.364, -35.152"
110 INPUT D1, D2:R1=RPD*D1: R2=RPD*D2:PRINT
120 PRINT "Enter year, month, day and hour...."
130 PRINT "--Example-- 1980, 10, 23, 14"
140 INPUT Y, M, DAY, H:Y=Y-1900
150 JD=365*Y+INT(Y/4)+(30.55*(M+2))-2*INT((M+7)/10)+DAY-93
160 IF Y-4*INT(Y/4) > .5 OR M>=3 THEN JD=JD+1
170 XO=(JD-29219)*1440:SNEP=SIN(.409138-4.31803E-12*XO)
180 PRINT "Solar azimuth and elevation data for "; CAL$
190 PRINT "date =";M;"/";DAY; "/"; Y+1900
200 PRINT "longitude =";D1, "lattitude="; D2:PRINT
210 PRINT "Time", "Azimuth",  "Elevation", "GHA",  "DEC"
220 FOR I=0 TO 55 STEP 5: GMT=I+60*H: T=XO+GMT
230 IF 15*INT(I/15)=I THEN PRINT
240 LM=4.88367+1.19464E-05*T
250 Y=6.23471+1.19458E-05*T
260 GST=GMT+399.254+2.73791E-03*T
270 TIME=100*H+I: C1=FNR(LM)
280 C1=C1+(.0334339-1.58913E-12*T)*SIN(Y)
290 C1=C1+(3.49304E-04-3.32759E-14*T)*SIN(2*Y)
300 DEC=FNS(SNEP*SIN(C1)):RA=COS(C1)/COS(DEC)
310 IF ABS(RA) >=1 THEN RA=(1-SGN(RA))*TWOPI/4:GOTO 340
320 RA=FNC(RA)
330 IF SIN(C1)<0 THEN RA=-RA
340 GHA=(TWOPI/1440)*GST-RA: GHA=FNR(GHA)
350 LHA=GHA-R1
360 EL=FNS(COS(R2)*COS(LHA)*COS(DEC)+SIN(R2)*SIN(DEC))
370 IF EL<0 THEN PRINT TIME, "*", "*", FNI(GHA/RPD), FNI(DEC/RPD): GOTO 430
380 AZ=(COS(R2)*SIN(DEC)-SIN(R2)*COS(LHA)*COS(DEC))/COS(EL)
390 IF ABS(AZ) >=1 THEN AZ=(1-SGN(AZ))*TWOPI/4: GOTO 420
400 AZ=FNC(AZ)
410 IF SIN(LHA) >0 THEN AZ=TWOPI-AZ
420 PRINT TIME, FNI(AZ/RPD), FNI(EL/RDP), FNI(GHA/RPD), FNI(DEC/RPD)
430 NEXT I:PRINT
440 PRINT "Command -- (go, nhr, nday, quit)":INPUT ANS$
450 IF ANS$="go" THEN H=H+1: GOTO 180
460 IF ANS$="nhr" THEN PRINT "Enter hour": INPUT H: GOTO 180
470 IF ANS$="nday" THEN GOTO 120
480 IF ANS$="quit" THEN END
```

to replace the RST type of report in the exchange because the longer DAH's are much easier to read than the DITS in the normal RST report.

So you say, "Why are you bothering me with all this information that I already know?" The reason is that if signals are weak (a common situation for those who can't rotate polarity) the exchange can be quite difficult unless you use a procedure that is understood by both operators. Timing is just as important as to what we are attempting to exchange for information. If we improve timing, send only information that is necessary and send it in a format expected by the receiving station, we can use the human brain as a "matched filter" and thereby improve copy as well as QSO's without increasing power or antenna gain! Let me give a few examples. It is common procedure on 70 cm to send only signal reports in the last 30 seconds of the 2 1/2 minute transmission period. However, I consistently hear stations sending call sets in this time frame and I would have known that he was not hearing me at all instead of thinking I may be getting a signal report. If you are not sending reports leave this time period blank.

An important procedure is the way we send call sets. Again we can improve our through put by standardisation. I recommend that we send only 1 x 1 call sets as follows: DL9KR de W1JR DL9KR de W1JR etc. The "de" tells you the order (and help's ID by others listening in) and breaks up the call signs in an orderly manner. Sending 2 x 2, 3 x 3 call sets etc. is confusing and fading may cause you to receive only one call but not the other. Next is the use of RST reports. They are fine but only if signals are "O" copy. Reserve any RST reports until you have received an "O" report especially on initial contacts. Another poor procedure I have noticed is reporting. When you are sending MR, OR or R, send them at least 1 to 2 minutes, not just in the last 30 seconds. If you are sending these reports you know the other station already has call sets so a few 1 x 1 call sets at the beginning (mainly for identification) is all that is needed. Give the other station all the reporting help you can.

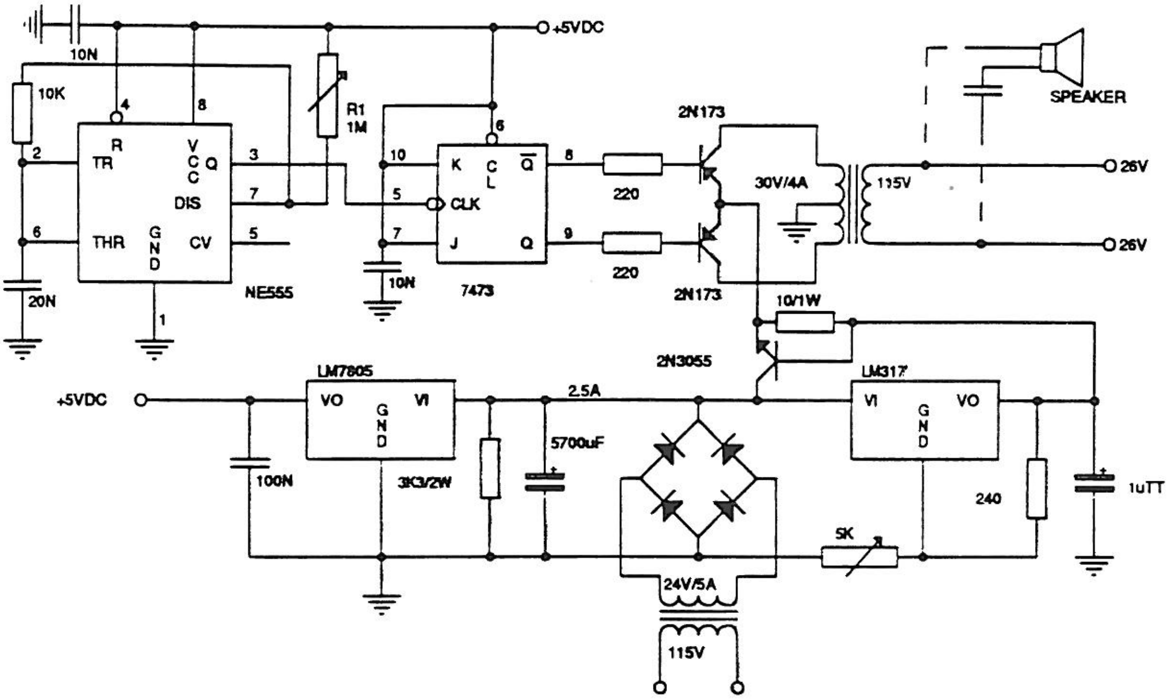
To sum this all up, we can improve our QSO rate if we standardise our procedures as follows: Never send in the last 30 seconds of your time block unless you are sending signal reports or "R" . Use only 1 x 1 call sets. Send RST type reports only after you are sure you are "O" copy by the other station. Send MR, OR or R for longer periods of time (greater than 30 seconds). I have prepared a handout sheet on the 70 cm QSO procedure and will be happy to send it upon receipt of an SASE. I hope this writeup will improve operating techniques as well as increase your number of QSO's. Any Comments?

4.15 400 Hz Synchro Power Supply

Gene Wasson K0UDZ - August 1982

If you ever think of going portable on EME, The circuit in Figure 4–9 might help you aiming your antenna to the moon. K0UDZ is using this sneaky 400 Hz supply for his radio campus direction and elevating system.

Figure 4–9: 400 Hz Synchro Power Supply



4.16 432/1296 MHz EME Operating Procedure

Allen Katz K2UYH - October 1982

4.16.1 Introduction

EME signals tend to be weak and relatively consistent, but with a short term fading which can turn a dah into a dit or even a pair of dits. It is this mushy signal quality due to liberation fading, rather than the low signal level, which makes EME communications difficult. Also signal paths are often non-reciprocal, due to polarisation rotation, allowing excellent reception in one direction, but none in the other direction.

Because of these unique EME signal characteristics, operating procedures, different from those used for other forms of VHF propagation, have been developed. Unfortunately no single EME operating system has been agreed upon for all bands. The system described below has been adopted for use on the 432/1296 bands. This system is designed to provide a maximum of feedback between transmitting and receiving stations and still meet the minimum requirements for a QSO as defined by the ARRL: exchange of calls, some other piece of unknown information - usually signal report - and confirmation of information reception.

4.16.2 Procedure

Schedule periods are broken up into 2.5 minute transmission segments, with the station most west of the international date line usually transmitting first. The 2.5 minutes are further broken down into two parts: The first 2 minutes (part A) and final 30 seconds (part B). Period B is reserved exclusively for the transmission of signal reports except during the initial period.

During the initial transmission period, calls are sent repeatedly for the entire 2.5 minute sequence. Procedure for subsequent transmission periods depend on what has been previously copied and can be classified as follows:

1. Copied nothing previously: Period A - transmit calls repeatedly. Period B - transmit nothing.
2. Copied signals but not full calls or reports: Period A - transmit calls repeatedly. Period B: transmit T's.
3. Copied full calls but no reports (or just T report): Period A - transmit calls repeatedly Period B - transmit appropriate signal report (M or O). T indicates insufficient signal quality for reception of calls. M indicates signal quality just adequate for reception of full calls (never sent unless full calls have been received). O indicates better than marginal copy (also indicates more consistent copy). RST reports may also be used, but they are not recommended for use on initial QSO's or when there is any question that the other station is copying.
4. Copied T reports and only part of calls: Same procedure as 2.
5. Copied reports of M or better but only parts of calls: Transmit T's for complete 2.5 minute period.
6. Copied full calls and reports of M or better: Transmit MR or OR as appropriate for the complete 2.5 minute period.
7. Copied reports and R (assuming previous reception of calls): Transmit R's (and 73's) for complete 2.5 minute period.

Figure 4–10: A sample EME QSO

Received before:	Period A:	Period B:
Initial period	VE7BBG de K2UYH	VE7BBG de K2UYH
Nothing heard	K2UYH de VE7BBG	Nothing
Signal heard	VE7BBG de K2UYH	T T T T.....
Nothing heard	K2UYH de VE7BBG	Nothing
Complete calls	VE7BBG de K2UYH	M M M M.....
Calls & report	MR MR MR MR MR..	MR MR .....
Report & R's	R R R 73 73 ...	R R R ...
R's	R R R 73 73 ...	73 73 ..

4.17 Sagittarius Sky Noise Charts

Drago Dobricic YU1AW - November 1983

The curve shown in Figure 4–11 is for the strongest of the sources and allows you to calculate either receiver temperature or antenna gain (you must know one to get the other) from the Y-factor (ratio in dB of the noise power received with your antenna pointed at Sagittarius to that with it pointed at cold sky) - Temperature is in °Kelvin and antenna gain used is referenced to an isotropic radiator.

4.18 Taking a Closer Look at Faraday Rotation

C.H. Hustig K9XY (MSEE) - January 1984

Any EME-er who has made at least a few QSO's via the moon has had to suffer the frustrations of Faraday rotation, a condition which changes the transmitted polarisation on penetration of the earth's ionosphere. The ionosphere can be properly classified as an anisotropic (non-reciprocal) medium of propagation. (See bibliography). Although the rotation of the signal depends on the angle of wave travel with respect to the local magnetic field direction and the degree of ionisation, it turns out to be identical in amount and sense for either forward or backward travelling waves. Thus if energy transmitted at the moon undergoes a 45° CW rotation on the way out, it will also suffer an additional 45° CW rotation (with respect to the ground station) on the way back. This is why echoes cannot always be heard. When this condition occurs between two EME stations who are trying to QSO, situations can arise where one station may be copying well while the other is copying nothing at all. It has been assumed (until now) that stations using fixed linear polarisation were faced with the prospect of no solution to this problem.

Figure 4–11: Sagittarius Sky Noise Charts

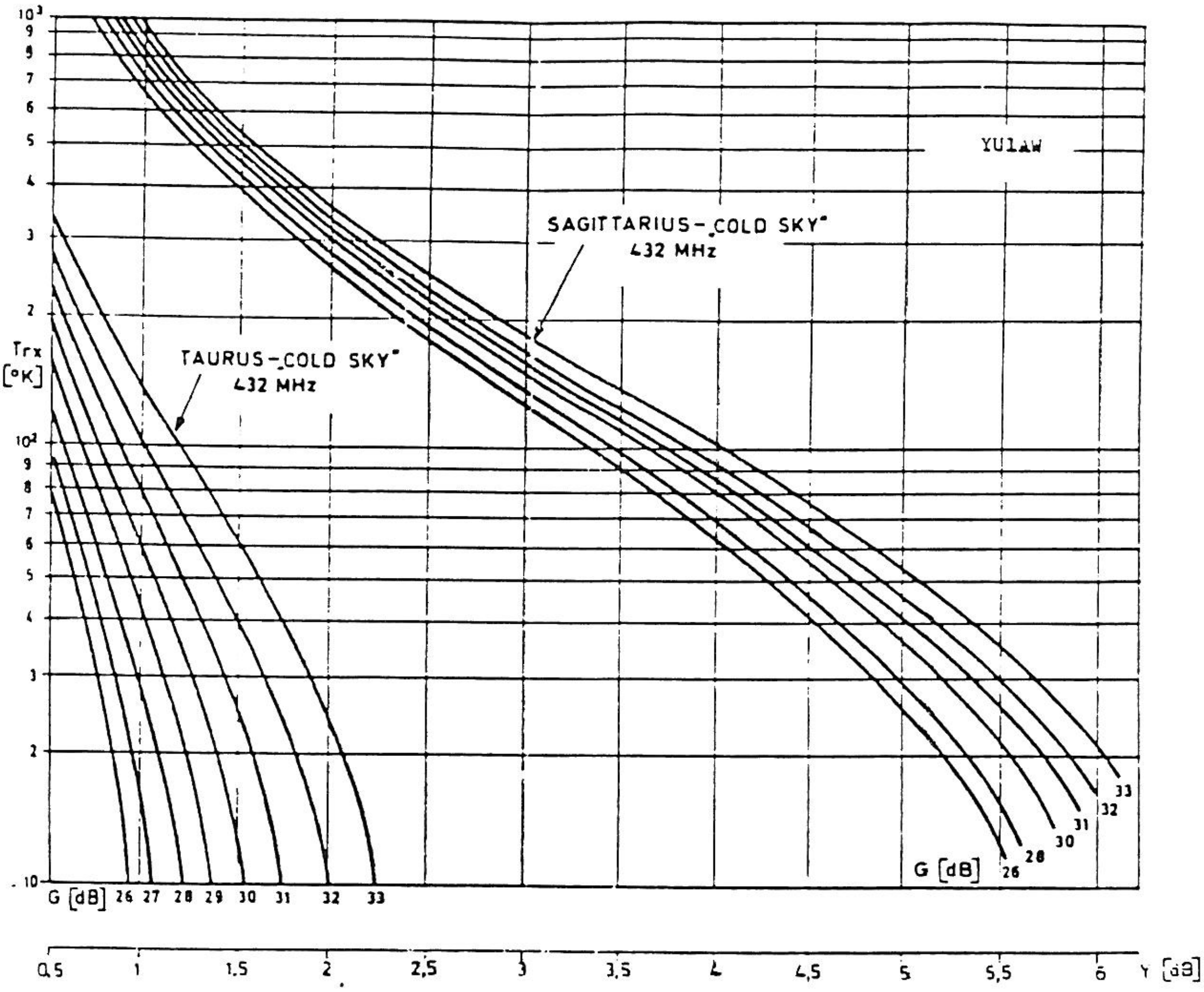


Figure 4–12: Faraday geometry

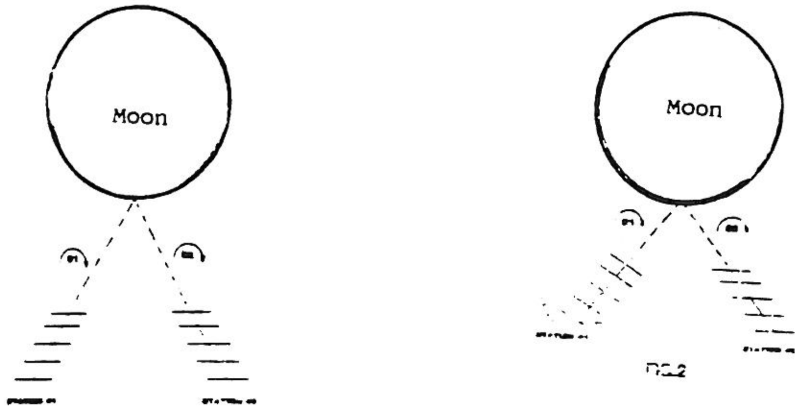


FIG.1

FIG.2

4.18.1 Determination of reciprocity conditions

If we examine the geometry of this problem, some interesting facts come to light. Let's assume a hypothetical situation in which two EME stations have antennas with the same polarisation in space. (See Figure 4–12a) Since the two stations are not in the same geographical location, the Faraday rotation angles θ_1 and θ_2 are not necessarily the same. For station #2 to hear station #1 the following condition must exist:

$$\theta_1 + \theta_2 = n \cdot \pi$$

It is also evident that under the above condition station #1 will also hear station #2. Now let's assume that the two antennas differ in polarisation by some arbitrary angle m, see Figure 4–12b, we can then say that for station #2 to hear station #1:

$$\theta_{12} = \theta_1 + \theta_2 = n \cdot \pi - \phi$$

and for station #1 to hear station #2:

$$\theta_{21} = \theta_2 + \theta_1 = m \cdot \pi + \phi$$

For reciprocity to occur:

$$\theta_{12} = \theta_{21} \Longrightarrow n\pi - \phi = m\pi + \phi$$

$$2\phi = (n - m)\pi \Longrightarrow \phi = k\pi/2$$

Where: $k = n - m$.

Thus reciprocity can only occur when the two station's antennas are polarised (in space) either parallel or perpendicular to each other (the latter condition is not entirely obvious).

Figure 4–13: Geometry for a AZ-EL mounted antenna

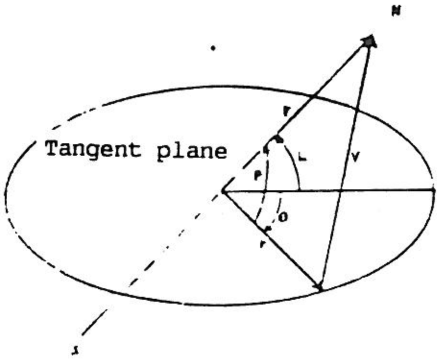


FIG.3

4.18.2 Determination of antenna Spatial Polarisation

If we chose the earth polar axis as a reference, the spatial polarisation angle of a polar mounted antenna is visibly obvious. For an AZ-EL mounted antenna, however the situation is quite a bit more complicated (See Figure 4–13). For the AZ-EL antenna with "horizontal" polarisation, the plane of polarisation is always parallel to the spherical tangent plane at the station's geographical coordinates.

Given:

A = Antenna azimuth
L = Station's latitude
P = Antenna polarisation with respect to polar axis.
$\theta = \pi/2 - A$ (the orientation of the antenna elements in the tangent plane)

Using vector addition:

$$|V| = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$

Where:

$x_1 = r\cos L$
$y_1 = 0$
$z_1 = r\sin L$
$x_2 = r\cos\theta$
$y_2 = r\sin\theta$
$z_2 = 0$

or:

$$V^2 = 2r^2 - 2r^2 \cdot \cos L \cdot \cos\theta$$

From trigonometry:

$$|\cos P| = \frac{r^2 + r^2 - v^2}{2r^2} = \cos L \cdot \cos\theta = \cos L \cdot \cos(\pi/2 - A) = \cos L \cdot \sin A$$

If we respect CCW polarisation angles with a (-) then $\cos P = -\cos L \cdot \sin A$ for $L - D \geq 0$ (where D=declination) when the moon is passing the south of the antenna, and $\cos P = \cos L \cdot \sin A$ for $L - D < 0$ when the moon passes north of the antenna. It is easy to see that, for two stations in widely separated geographical locations and having AZ-EL mounted fixed-linear polarised antennas, the reciprocity condition is seldom satisfied.

4.18.3 Determination of Transmit Polarisation Offset

For stations having polarisation control, the proper transmit polarisation for working a fixed polarised station can now be determined using the following method:

1. Calculate the distant station's spatial polarisation P_1 from above.
2. Determine the spatial polarisation at which you receive maximum signal (P_2).
3. Find P2-P1 = θ_{12} $(-\pi/2 < \theta_{12} \leq \pi/2)$
4. To set $\theta_{12} = \theta_{21}$:
    - Rotate CW $2(90 - |\theta_{12}|)$ if $\theta_{12} \geq 0$
    - Rotate CCW $2(90 - |\theta_{12}|)$ if $\theta_{12} < 0$

4.18.4 Conclusions

Based on Faraday rotation considerations, an AZ-EL mount for stations using fixed linear polarisation is a poor choice. Stations using fixed linear polarisation and polar mounts should hear each other simultaneously. Antenna polarisation parallel or perpendicular to the polar axis should perform equally as well. Polar mounting your antenna will not help unless most other stations do the same.

4.18.5 Bibliography

1. Ramo, S. Whinnery, J.R., van Duzer, T. Fields and Waves in Communication Electronics, John Wiley & Sons inc., New York, London, Sydney. 1965, pp. 514-519
2. Robert E. Collin, Foundations for Microwave Engineering, McGraw Hill 1966, pp. 269-299
3. H.A. Atwater, Introduction to Microwave Theory, McGraw Hill 1962, pp. 206-212
4. A.L. Lance, Introduction to Microwave Theory and measurements, McGraw Hill 1964 pp. 167-171

4.19 Microwave Radiation Safety

Chip Angle N6CA - February 1984

In the United States, the generally accepted safe level of human exposure to microwave radiation is 1 mW/cm^2. For one Watt of average power the area of illumination would be 1000 square centimetres or a circle of about 14 inches. In the Soviet Union and some Eastern Europe countries the generally published maximum level is 10fW per cm^2. This is 20 dB lower than the US specification. The large discrepancy is unsupported by tests. No US run test has ever been able to reproduce the results of the Soviet tests. One can only speculate as to the motives for this type of data. The biological effects of microwave radiation are localised heating of tissue and organs. This heating damages cells and can be permanent. Skin burns from microwave radiation can take months to heal. Never touch an antenna with RF power applied, especially at 1296 MHz.

As far as amateur radio is concerned, microwave radiation levels will generally be well below the US recommended level since high power is generally beyond the capabilities of most amateurs. RF fields can be simply measured with a resonant 50 ohm dipole and a reasonably accurate power meter. The aperture of this dipole can be roughly treated as a circle whose diameter is the length of the dipole. The average 1296 MHz dipole with a length of about 4.5 inch will have an aperture of about 100 square centimetres. By positioning the dipole around the source to be measured and observing the maximum reading on the power meter, simply divide the reading by 100 and you will have a good estimate of the power density in mW/cm^2. All transmitting equipment above 420 MHz should be measured this way to verify safety. The LCA amplifier was measured with this scheme. The amplifier was running into a 50 ohm dummy load. RF output was 250W CW. The measured level at 3 inches from the anode of the 7289 tube was slightly less than 0.1 mW/cm^2. In spite of this low level, never place any part of your body that close to any RF generating equipment. To establish a tangible reference for safety, one watt of 1296 RF going into a dipole on the work bench can be harmful at distances closer than two Feet. Here are a few DO NOT's :

- Never touch an antenna with RF power applied.
- Never stand in front of an antenna with RF power applied.
- Never operate an amplifier with safety shields removed.
- Never guess at RF levels, measure them first.
- Keep all UHF antennas as high as possible to avoid human exposure to side lobe RF levels.

- Use good quality, well constructed coaxial cables for all interconnects to avoid RF leaks.
- THINK SAFETY FIRST.

4.20 RF Hazards Revisited

Roger Blackwell G4PMK, Ian White G3SEK - April 1984

In the February NL, Chip Angle (N6CA) produced a useful list of "DO NOT's" for protection against RF hazards. As radio amateurs and radiation protection professionals, we'd like to comment further.

Did you notice that all of Chip's "DO NOT's" are things a good RF engineer shouldn't do anyway? Before you ever heard of RF hazards, you already knew that RF sources should be shielded, and transmission lines shouldn't leak RF. You already knew that an antenna should be located away from RF-absorbing obstructions (including human bodies). You already knew that it isn't necessary to use lots of power when tuning up antennas, and that you cannot make good measurements if you're standing in the RF field. And you already knew that safety is important! In other words, good RF engineering is also good RF-hazard protection. But we think that Chip has understated the exposure limits and overestimated the risks. The limit of 1mW/cm^2 quoted by Chip presumably comes from the American National Standards Institute (ANSI) standard. But 1mW/cm^2 only applies at 30-300 MHz where whole bodyresonances can increase rf absorption. For the range 300-1500 MHz ANSI recommends a steadily rising limit of (f/300)mW/cm^2, ie 1.44mW/cm^2 at 432 MHz and 4.32mW/cm^2 at 1296 MHz. The ANSI limit levels of at 5mW/cm^2 for 1.5 GHz and up. Similar limits are proposed in Britain by NRPB, the National Radiation Protection Organisation for which we both work.

Exposures at these limits are not hazardous: that's how the limits were set! You'd need well over 100mW/cm^2 to produce a skin burn like Chip describes (or damage to the eyes, a more serious hazard), so the limits have large safety margins. You'd also need several minutes' exposure before suffering an injury.

If the total power is 7W or less, the ANSI limits can be exceeded at frequencies up to 1 GHz. The reason for this relaxation in ANSI is that low RF powers at low frequencies just can't be concentrated into a small enough volume to overheat and damage the masses of body tissue involved. There's no significant difference between 1 GHz and 1.3 GHz in this respect, so antenna testing using a few Watts on 432 and 1296 MHz (though you could do it better with a return loss bridge and a few milliwatts). 1W into any 1296 MHz antenna is not hazardous, at any range. The power density at a distance R from an isotropic source is simply: (watts)/(surface area or sphere, radius R) This relationship is valid for physically and electrically small antennas like dipoles, and applies for distances down to about 1/6λ. For non-isotropic antennas, multiply by the power gain to obtain the worst case power density. So the power density at 2 ft from a 1296 MHz dipole fed with 1W is: $(1000mW/(2\cdot\phi\cdot R^2)+2.15dB)$, ie about 35uW/cm^2. This calculation only works for small antennas without significant gain, or at long distances from large antennas with gain (see below). Hazards are most likely to arise when a lot of RF power is concentrated in a small aperture area, especially any kind of waveguide structure or a small beam like a dish feed. We have measured 20mW/cm^2 at 1.2 meters down the centerline of a W2IMU horn fed with 100W at 1296 MHz.

The maximum possible power density from an aperture antenna is 4W/A where W is RF-Watts and A is the aperture area in cm^2. 4W/A also applies to dishes, beyond the focal plane, but now the rf is spread over the whole dish (area A) and the power density drops considerably. Note that the bigger the dish, the less the RF hazard! Peak power densities for single Yagis are harder to calculate, though for big arrays you can assume A is the overall frontal area of the array. If the antenna is working properly, sidelobes or spillover should be no hazard at any amateur power level, so aiming at a high moon is always safe provided you keep people out of the antenna itself. It's also safe behind a dish that is bigger than you are.

We sometimes get questions like "Is it safe to stand by the rim of my dish, or by the side of my Yagis?" Since there is no need to stand in such places when the full power is on, the only sensible answer to such questions is "Go stand somewhere else".

You can always keep people away from potentially hazardous areas close to your own antenna, but you can't really control what your neighbours do in their own houses and backyards. However, at distances of more than a few dish diameters the beam is spreading out, and the power density is dropping by the inverse square law. You can calculate the power density at a distance R using the $(watts) \cdot Gi/4 \cdot \phi \cdot R^2$ formula. On the axis of the beam, Gi is the antenna gain over isotropic; or gain minus sidelobe suppression at other angles. At very short distances this formula is not valid; you can always disregard any answer greater than 4W/A. With a high moon there's never a problem. And even with a low moon or your tropo system, you'll find that your environmental power densities in places where neighbours might be are below the ANSI limits. Remember, if nobody's there when you're transmitting, there is no RF hazard.

So Chip is right to say "never guess at RF-levels"; though it may be easier to calculate RF levels (as above) than to measure them accurately. Professional survey instruments are basically broad band, calibrated field strength meters, and we all know how hard it can be to get sensible readings by waving a field strength meter around! Chip's method with a dipole and power meter could be even more inaccurate, especially close in, because the dipole and the lead to the power meter will distort the rf field. Professional instruments go to great length to avoid field distortion.

We hope these notes have given you some useful perspective about RF hazards. The important thing to remember is that there's never any good engineering reason why anybody should need to be exposed to RF hazards in amateur radio.

4.21 Program to Calculate Stellar Noise Sources

Allen Katz K2UYH - July 1984

To be able to measure one's station performance, the exact position of stellar noise sources might be of interest. Figure 4–14 lists a star tracking program based on a program from R.L. Tester, W6YVO, which provides the position of common stellar noise sources for a given time and location. The program is suitable for GWBASIC, but should be usable for any other computers with slight modifications.

Figure 4–14: Program to Calculate Stellar Noise Sources

```
10 PRINT "Star Tracking Program V1.0 7/1/84"
20 REM by A.Katz K2UYH -based on program from R.L. Tester W6YVO
25 REM provides position of common stellar sources for a given
26 REM time and location
29 PHI=3.1415927#
30 PRINT: PRINT: INPUT "call"; C$: RD=180/PHI
40 IF C$="K2UYH" OR C$="" THEN LA=40.216/RD: LO=74.766:GOTO 70
50 PRINT :INPUT "lattitude in deg's, min's"; L1, M1: LA=(L1+M1/60)/RD
60 PRINT :INPUT "longitude in deg's, min's"; L2, M2: LO=(L2+M2/60)
70 PRINT :INPUT "Name of stellar object";N$
80 REM *********************Star Data*****************
90 NS$=LEFT$(N$,3): IF NS$="CAS" THEN RA=23.35: DE=58.55/RD: GOTO 220
100 IF NS$="CYG" THEN RA=19.9666: DE=40.6/RD: GOTO 220
110 IF NS$="TAU" OR NS$="TOR" THEN RA=5.533: DE=22/RD: GOTO 220
120 IF NS$="SAG" THEN RA=17.7 : DE=-28.91666/RD: GOTO 220
130 IF NS$="AUR" THEN RA=4.95: DE=46.5/RD: GOTO 220
140 IF NS$="VIR" THEN RA=12.466: DE=12.7/RD: GOTO 220
150 IF NS$="OME" THEN RA=18.3: DE=16.667/RD: GOTO 220
160 IF NS$="CEN" THEN RA=13.367: DE=-42.8/RD: GOTO 220
170 IF NS$="443" THEN RA=6.233: DE=22.6/RD: GOTO 220
180 REM **********************************************
```

Figure 4–14 Cont'd on next page

Figure 4–14 (Cont.): Program to Calculate Stellar Noise Sources

```
190 INPUT "Object's Right Ascension in hours,min's";RH, RM
200 INPUT "Object's Declination in Deg's, Min's";DD, DM
210 DE=DD+DM/60: RA=RH+RM/60: DE=DE/RD
220 PRINT: INPUT "Year"; Y: Y=Y/100: Y=INT(100*(Y-INT(Y))+0.1)
230 IF Y/4=INT(Y/4)  THEN LY=1 ELSE LY=0
240 IF Y=84 THEN B=17.409421# ELSE IF Y=85 THEN B=17.359625#
 ELSE IF Y=86 THEN  B=17.375539#
 ELSE IF Y=87 THEN B=17.391453#
 ELSE B=17.38:PRINT "Y?"
250 INPUT "Month";MM: IF MM<1 OR MM>12 THEN 250
260 INPUT "Day"; DD: IF DD<1 OR DD>31 THEN 260
270 RESTORE: FOR I=1 TO MM:READ DA: IF I=MM THEN DY=DD+DA: NEXT
280 DATA 0,31,59,90,120,151,181,212,243,273,304,334,365
290 IF MM>2 THEN DY=DY+LY
300 TO=DY*0.0657098-B: CC=0: CP=6
310 PRINT: INPUT "Time Interval in min's"; DT: IF DT=0 THEN DT=30
320 PRINT: INPUT "Do You Want a Hardcopy (Y/N)";Q$: DV=1
325 IF Q$="Y"
      THEN OPEN "LPT1:" FOR OUTPUT AS #1 ELSE OPEN "SCRN:" FOR OUTPUT AS #1
330 PRINT #1,: PRINT #1,:
      PRINT #1, C$ "AZ-EL INFORMATION FOR "NS$" IN GMT FOR " MM"/"DD"/"Y
340 PRINT #1,: PRINT #1, TAB(10) "GMT"  TAB(24)  "AZ"  TAB(38)  "EL"
350 PRINT #1, TAB(10) "----"  TAB(22) "------" TAB(36) "------"
360 FOR T=0 TO 1440 STEP DT: TS=INT(T/60)*100+T-60*INT(T/60)
370 TG=T/60*1.002738+TO
380 TL=TG-LO/15:IF TL>24 THEN TL=TL-24 ELSE IF TL<0 THEN TL=TL+24
390 TH=15*(TL-RA): IF TH<0 THEN TH=TH+360
400 TH=TH/RD: E3=COS(LA)*COS(TH)*COS(DE)+SIN(DE)*SIN(LA)
410 E2=SQR(ABS(1-(E3*E3))): EL=ATN(E3/E2): IF EL<0 THEN 520
420 A2=SIN(DE)/(COS(LA)*COS(EL))-(SIN(LA)/COS(LA))*(SIN(EL)/COS(EL))
430 A1=SIN(LA)*SIN(DE)+COS(LA)*COS(DE)*COS(TH)
440 A3=(SIN(TH)*COS(DE))/(SQR(ABS(1-A1*A1)))
450 AZ=ATN(A3/A2)
451 IF A2<0 THEN AZ=PHI-AZ ELSE IF AZ>0 THEN AZ=2*PHI-AZ ELSE AZ=-AZ
460 PRINT #1, TAB(10);: PRINT #1, USING "####"; TS;
461 PRINT #1, USING "###########.##"; AZ*RD, EL*RD
470 IF DV=0 THEN CC=CC+1
471 IF INT(CC/20)=CC/20 THEN INPUT "Hit CR to continue"; O$
480 IF DV<>2 THEN 520 ELSE IF CP=54 THEN 480 ELSE CP=CP+1: GOTO 520
490 CP=4: PRINT#DV, CHR$(12)
500 PRINT #1: PRINT #1, TAB(10) "GMT" TAB(24) "AZ" TAB(38) "EL"
510 PRINT #1, TAB(10) "----" TAB(22) "------" TAB(36) "------"
520 NEXT: PRINT: INPUT "Want to continue (Y/N)";Q$
530 IF Q$="Y" THEN PRINT: GOTO 220 ELSE END
```

4.22 RF Fields Indicators

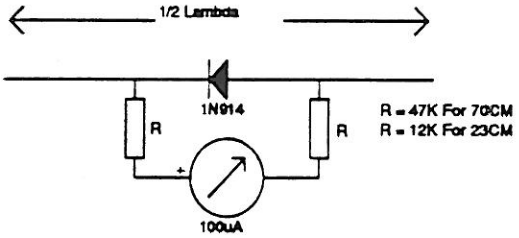
Ian White G3SEK, Roger Blackwell G4PMK - May 1985

These indicators are intended to show if RF fields are large enough to require precautions against possible RF hazards (April 1984 NL). Each indicator uses a 1N914 / 1N4148 detector diode in the centre of a half wave dipole, and the voltage is ampled by a pair of high-value resistors leading to a meter of about 100 micro Amps full scale deflection. The indicators are sensitive to the E field, and RF power density is proportional to E^2.

These are indicators, not measuring instruments. Close copies of our prototypes should be accurate enough without further calibration. With a 100fA meter and the resistor values shown, full scale means about 0.5mW/cm^2 on the 432 MHz model, and 1mW/cm^2 on 1296, as measured using professional instruments in an anechoic chamber. Full scale readings are thus about a quarter of the ANSI limits for continuous exposures.

When making the indicators, use no unnecessary metal which might distort th RF field. We build our indicators in carved-out chunks of Styrofoam. Use a small meter with a plastic case. Dipole lengths are not critical within a few percent, though the diode should be soldered in with zero lead lengths. Cut the resistor leads short at the diode side and use the full uncut lead length to connect to the meter, but don't extend the meter leads. If the meter's FSD isn't exactly 100fA, you can compensate by changing the 2 resistors to give the same full scale voltage.

Figure 4–15: RF Fields Indicator



To use the indicator, mount it on a long wooden stick and hold it well clear of your body. Search around the area you're interested in, and always rotate the dipole to maximise pickup. At ranges at less than a few wavelengths from an antenna, there will be fluctuations caused by the periodic nature of mutual coupling to a dipole, so look for the maximum and minimum values. These indicators require more skill in use than professional broadband isotropic instruments, but are also about 1000 times cheaper.

With normal EME power into the 8 yagi 432 MHz array at a centre height of 10ft and elevations greater than about 20°, we found only very small fields at distances greater than a boomlength, walking around the array. The fields began to climb steeply at sideways distances less than about a wavelength. At zero elevation the indicator read about half-scale for at least 100ft down the antenna. Antennas mounted well above ground cause no problems, even at zero elevation: the ground level maximum occurs where the edge of the main lobe touches the ground, and it's to weak and too distant to create significant ground level fields. All these observations have been confirmed using professional instruments.

You can also get some general indication of direct radiation from feeders and amplifiers, though the main clue to excessive RF leakage will probably be electronic misbehaviour. Cure that and you have probably cured the RF hazard too.

RF exposures even at the ANSI limits are not unsafe (April NL), so don't panic if you find indicator readings near or above full scale. Be aware of RF hazards, but also be aware that you can always control them.

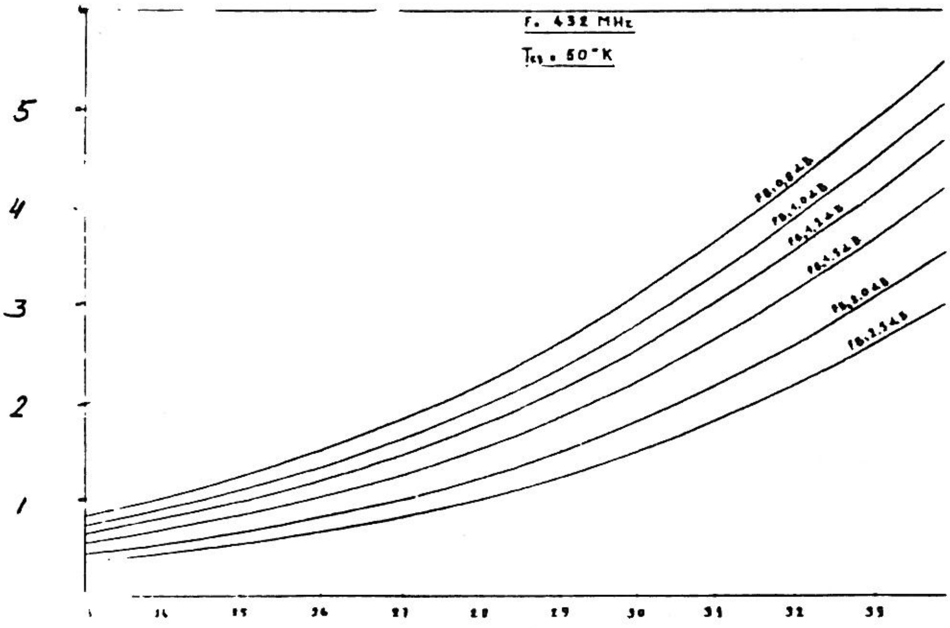
4.23 Cygnis "A" Noise Curves

Franck Tonna F9FT - September 1984

The level of the radio-source "Cygnis-A" as function of the antenna gain. Curves in Figure 4–16 show the different noise figures related to this radio-source.

The Position of "Cygnis-A" : Right Accention is 19h57m45s and Declination is 40°36'

Figure 4–16: Cygnis-A Noise Curves



4.24 Doppler Shift on EME

Antonin Jelinek OK1DAI (OK1KIR) - April 1984

The best test of the whole EME equipment is listening to own echoes. With a receiver bandwidth of 100 to 200 Hz it is worth having a prediction of the Doppler frequency shift, specially on the SHF bands. This fact has led us to the summarisation of simplified formulas and from these we have worked out graphs for this purpose. From our experience from both 432 and 1296 MHz we assume that the Doppler shift is not only our problem and we think that the graphs may be useful to other operators too. Besides the prediction of ones own echoes the graphs enable quick determination of the frequency shift of the other station and they are worked out for 432 and 1296 bands. If using the graphs for other frequencies F_x the graph reading should be multiplied by ratio F_x/F_{graph}

4.24.1 Frequency shift of own echoes

The frequency shift of ones own echoes is defined as:

$$\Delta f_0 = \Delta f_g + \Delta f_M \qquad (4\text{–}1)$$

where:

Δf_g - freq. shift caused by influence of the Earth.
Δf_M - freq. shift caused by influence of the Moon.

Influence accounted for the rotation of the earth, declination of the moon and mutual rotation of the earth with the moon-graph (Figure 4–17a):

$$\Delta f_E = \frac{4\lambda \cdot 6370 \cdot \cos\psi \cdot \sin t \cdot \cos\delta}{(1 + 0.034 \cdot \cos t) \cdot 24 \cdot 3.6 \cdot \lambda} \qquad (4\text{–}2)$$

where:

λ - wavelength in meters
ψ - geographic lattitude in degrees
δ - declination of the Moon in degrees
t - hour angle in degrees

Operators using polar mounting can read the hour angle on the main rotable axis of the antenna while those using El-Az mounting will find the hour-angle converted into time in hours on the same axis in the graph in Figure 4–17a (Average orbit length of 24.85 hours is introduced) It does not matter if the declination is positive or negative. For determination of the starting point one should know the time of culmination of the moon in one's particular location (eg. according to an annual astronomical handbook). Simplified formula for Δf_{Emax} (t=90°)

$$\Delta f_{Emax} = \frac{926 \cos\psi \cdot \cos\delta}{\lambda} \qquad (4\text{–}3)$$

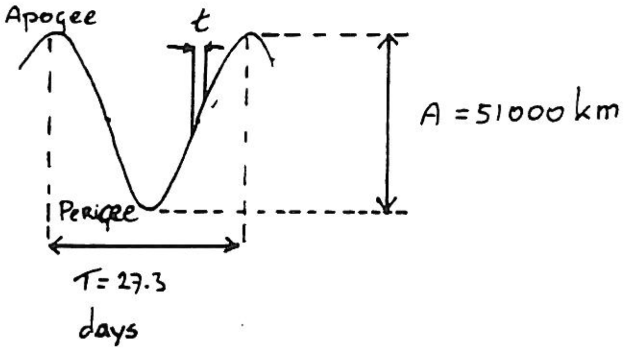
For the 50th parallel we obtain: for 432 MHz $\Delta f_{Emax} = 865$ Hz and for 1296 MHz $\Delta f_{Emax} = 2590$ Hz. Those values are positive at the moonrise and negative at the moonset. Station having lattitude (ψ_x) other than 50° should multiply the graph indication Δf_E by coefficient K for lattitude change. (The value is the same for northern as well as southern hemispere).

$$k = \frac{\cos\psi_x}{\cos 50\,\mathrm{deg}} = 1.56 \cos\psi_x \qquad (4\text{–}4)$$

Δf_{EX}, which stands for Δf_E at lattitude ψ_x, can be read from Figure 4–17b.

$$\Delta f_{EX} = k \cdot \Delta f_t$$

Influence accounted for the motion of the moon between apogee and perigee. (Figure 4–17c)



Maximum velocity of the moon is defined as:

$$V_{max} = \frac{A}{2} \cdot \frac{2\pi}{T} \cdot \cos\frac{2\pi}{T} \cdot t$$

from where we get $V_{max} = 68$ meters/sec

Influence of the moon on the frequency: $\Delta f_M = \frac{2V}{\lambda}$. This influence amounts on 432 MHz to $\Delta f_{Mmax} = 196$ Hz and on 1296 MHz to $\Delta f_{Mmax} = 598$ Hz. These values are the same for all terrestial stations. When the moon is going from apogee to perigee these values are positive, while in the opposite direction they are negative. So that we can find out the values of ΔF_M the date of apogee and perigee should be known (again from atronomical handbook).

Example:

Our station is located on the 40th parallel ($\psi_x = 40°$), freq. is 1296.030 MHz date is 12 August, time is 10:20 local time. From an astronomical handbook we have found out that the declination of the moon is 10°, the moon culminated at 06:50 local time and apogee was on the second August. We want to know the frequency of our own echoes. It is 4.5 hours after culmination, so for this and 10° declination we find in Figure 4–17a Δf_E = -2.2 kHz. For lattitude different from 50° we convert this indication with the help of Figure 4–17b to Δf_{EX} = -2.6 kHz. From Figure 4–17c we can read for 10 days after apogee Δf_m = +0.42 kHz.

Total shift: $\Delta F = \Delta f_{EX} + \Delta f_M = (-2.6) + 0.42 = -2.18$ kHz, so the frequency of the echoes is 1296.02792 MHz.

4.24.2 Shift of frequency (Δf_X) of the other station (X)

$$\Delta f_X = \frac{\Delta f_{E0}}{2} + \frac{\Delta f_{EX}}{2} + \Delta f_M$$

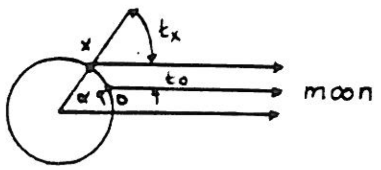
where:

Δf_{E0} - shift of one's own freq. caused by the earth.
Δf_M - freq. shift caused by the Moon. (Figure 4–17c)
Δf_{EX} - shift of freq. of the other station caused by the Earth.

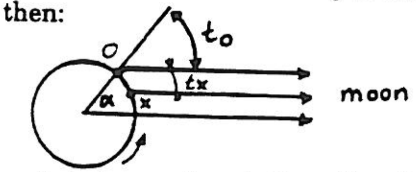
For Δf_{EX} however, we must know the geographical coordinates of the other station. The angle α is the difference between geographical longitudes of both stations. Simplified determination of the hour angle t_X of the other station:

a) If both stations see the moon either rising or setting and the other station (X) is further from the moon than the own station then:

$t_X = t_0 + \alpha$



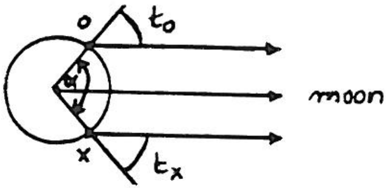
b) If both stations see the moon rising or setting and the other (X) is closer to the moon than the own station (O) then:



$t_X = t_0 + \alpha$

c) If the moon is between the stations X and O then:

$t_X = t_0 + \alpha$



In the above formulas the diameter of the earth is not considered - max. error is 0.5° and can be neglected. For the determination of the hour angle t_X we must read the value of Δf_E in Figure 4–17a. Then this value should be converted with the help of Figure 4–17b for lattitude change. (ψ_x is the lattitude of the other station X) into f_X.

4.25 Polar Mount Parallax Correction

Antonin Jelinek OK1DAI (OK1KIR) - June 1985

As our beamwidth on 2.3 GHz is only 1.9° at -3 dB we have been forced to consider the parallax of the moon during directing our dish with polar mount to the moon. As the value of declination δ given in our astronomical handbook is geocentric i.e. related to the centre of the earth, we have to convert this value to a different one which will be adjusted at the antenna mount. The right handed graph in Figure 4–18 shows the relation between hour-angle t and parallax angle q_d. The value of q_d is in fact the error which has to be subtracted from the value of declination.

Example 1: $t = 0\,\text{deg}$ and $\delta = +20\,\text{deg}$ the real declination at antenna will be $\acute{\delta} = +19.5\,\text{deg}$

Example 2: $t = 0\,\text{deg}$ and $\delta = +20\,\text{deg}$ then $\acute{\delta} = -20.95\,\text{deg}$

The other hand of the graph is a mirror image of the graph shown. The left hand graph in Figure 4–18 shows the relation between the parallax of the moon and the hour-angle. In our case we compensate the q_t by means of an eccentric which deviates a sensor sensing the position of the antenna. A simpler but a little less accurate is a linear compensation by means of increasing the range and speed of rotation of the antenna. For example 180° hour-angle is extended to 181.3° at the same duration of revolution - that is increased speed of turning the antenna. The graphs apply for lattitude ψ=50° and if a different lattitude is to be determined the following relations are used:

$$\tan q_t = \frac{\cos\psi \cdot \sin t}{\cos\delta \cdot \cot\pi - \cos\psi \cdot \cos t}$$

For determination of q_d, subsidiary values of γ, χ and β will be first figured out.

$$\tan\chi = \frac{\cos t}{\tan\psi} \qquad \chi = \frac{\sin\psi}{\cos\gamma} \qquad \beta = 90 - \delta - \gamma$$

which will lead to:

Figure 4–17: Doppler shift on EME

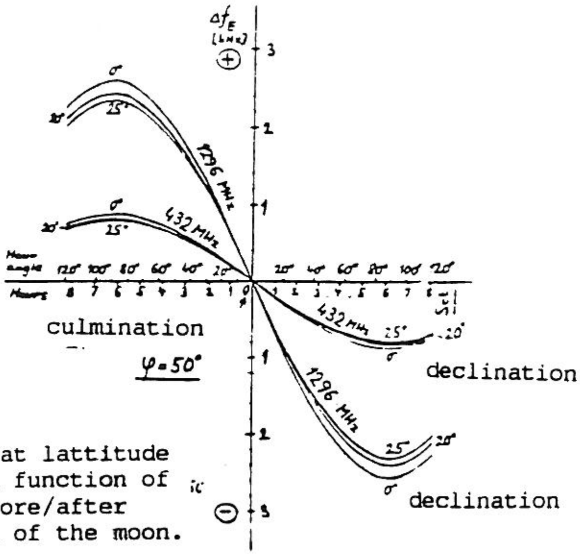


Fig.1.

Freq. shift at lattitude 50 deg. as a function of the time before/after culumination of the moon.

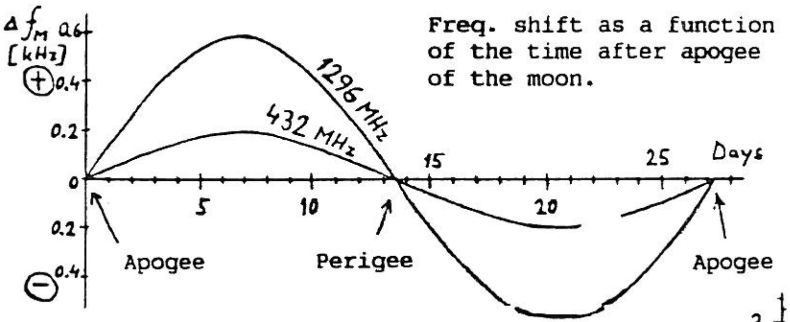


Fig.2.

Freq. shift as a function of the time after apogee of the moon.

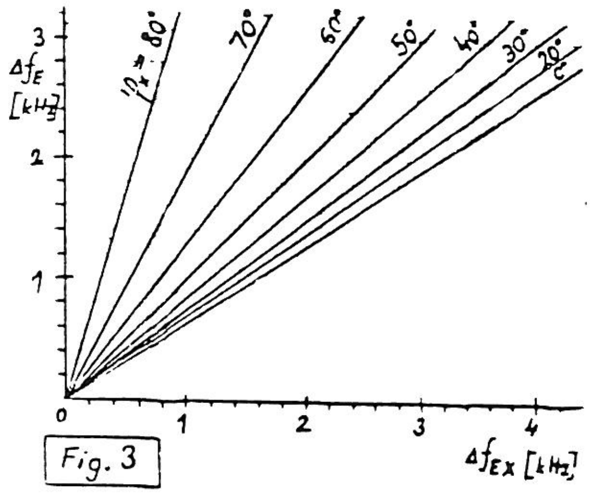
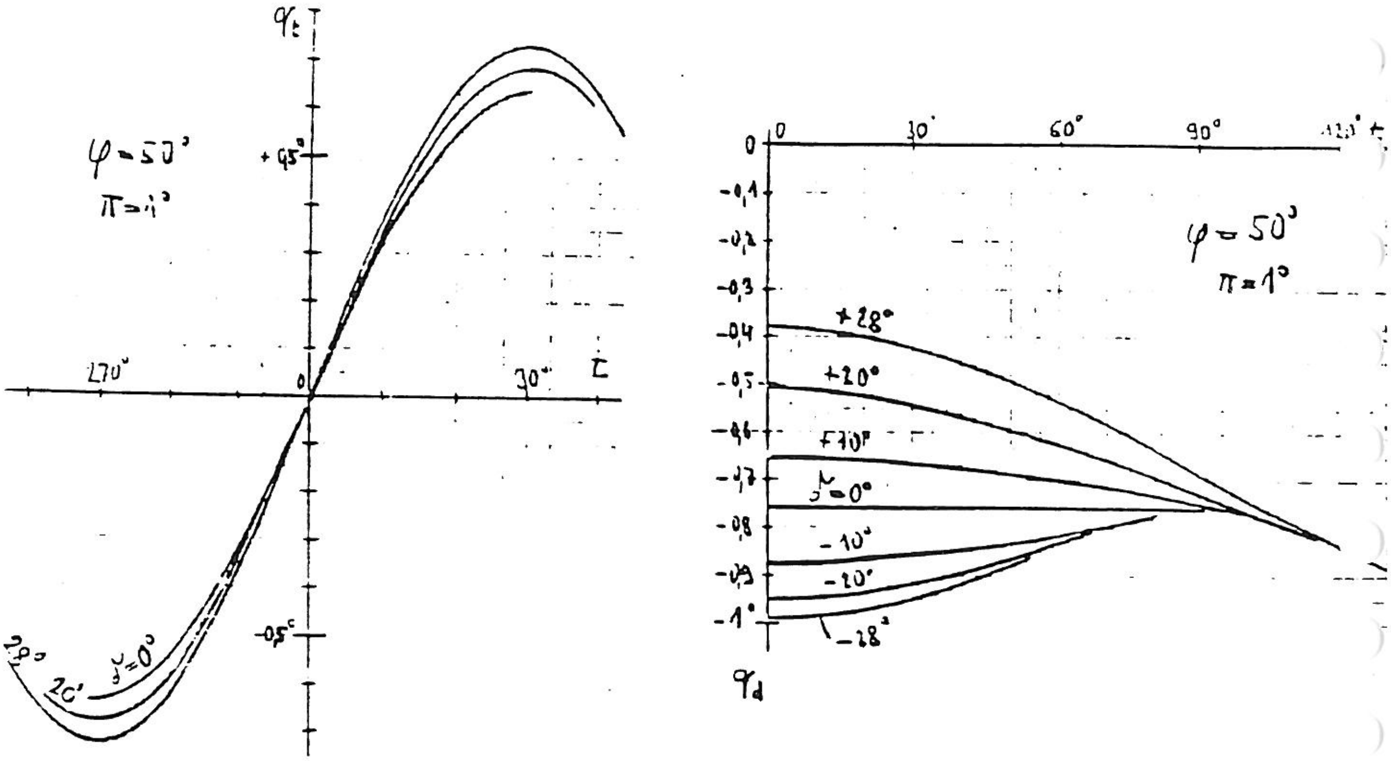


Fig. 3

$$\tan q_d = \frac{\sin\beta\cdot\chi}{\cot\pi - \cos\beta\cdot\chi}$$

The values in the graphs correspond to the time close to perigee when the value of horizontal equator parallax π=1°. For apogee when π=54° the value from the graph should be multiplied by 0.9. For the sun and other celestial bodies the parallax can be neglected because of their distance. Considering the given facts has helped us to complete our first 13cm QSO during a time of invisible moon.

Figure 4–18: Parallax Relationships



4.26 RX NF Measurements using Sky and Ground Noise

Charles Suckling G3WDG - August 1985

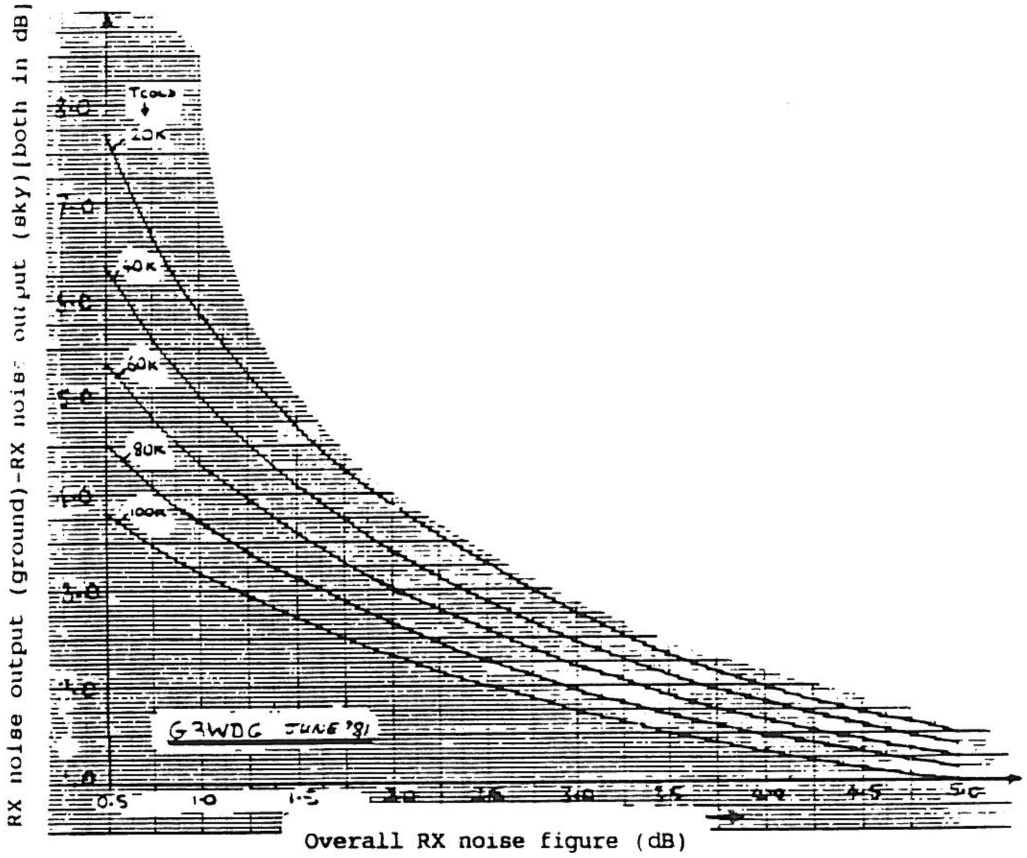
The graph in Figure 4–19 shows difference in RX noise outputs (in dB) with antenna pointing at ground and at cold-sky, as a function of RX noise figure. Below about 1 GHz, accuracy may be reduced due to ground reflections of cold sky! Various "cold" antenna temperatures are given. For example a dual-mode feed horn at 1296 MHz is 20°K, a 0.6 f/D dish at 1296 MHz is 50-60°K and a 0.6 f/D dish at 432 MHz is around 80°K. Always have the receiver AGC off during measurements. For cold measurement that antenna is clear of any local buildings, trees etc. For ground measurement, point antenna sufficiently below horizon to get max. noise. With horns and other dish feeds, do not hold antenna close to ground, or VSWR may change enough to affect RX noise output and ruin measurement accuracy.

4.27 Libration Fading

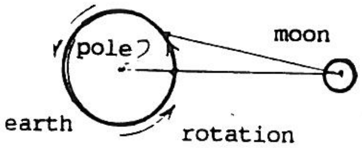
Dick Turrin W2IMU - October 1985

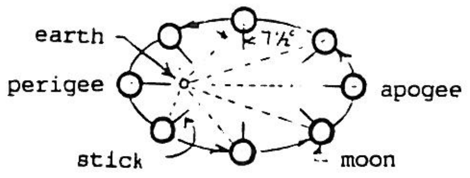
Libration fading, the bain of EME communication. Libration fading is caused by the multipath reflections from the rough surface of the moon, and the relative motion between the earth and the moon called liberation. This motion is very slow and may be described geometrically by 3 components:

Figure 4–19: Cold Sky versus Ground Noise

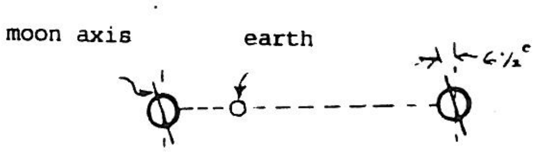


1. The earth rotation causes an observer on the earth's surface to view a slightly different area of the moon as the observer moves. part of the observer motion is in line with the path and gives rise to doppler frequency shift, but the transverse (sliding sideways) motion causes liberation fading. This component of liberation fading is maximum when the moon is in transit (highest elevation), is a daily effect and among other factors varies as cosine (the observers lattitude). It is therefore maximum for an observer on the equator and decreases at high lattitudes.





2. The moon's slightly elliptical orbital path and its rotation on its own axis with constant angular velocity, presents to an observer on earth a slightly different surface as the moon orbits around the earth with alunar period of about 27.3 earth days . The transverse (sideways slip) of the moon surface is maximum at apogee and perigee and aptly described by researchers at MIT. "If a stick is placed in the moon surface at perigee pointing directly toward the centre of the earth it would do so again only at apogee. In between there would be an angle of up to 7.5x between the line of sight to the earth centre and the stick."



3. Another component of moon liberation is caused by the fact that the rotational axis of the moon is not perpendicular to its orbital plane, but is tilted by 6.5x. This tilt causes an observer on earth to view an area of the moon above and below the moons equator as the moon orbits around the earth, as shown by the drawing below. The effect is maximum at the nodes of the lunar orbit, not at apogee and perigee.

The maximum possible moon liberation rates of components (2) and (3) are about equal and each about 1/3 of the earth component (1). Complicated mathematical formulas can be written to describe the geometrical motions involved. These formulas can predict liberation minimas with good accuracy for any EME path. Another TECH NOTE will present the formulas and how to apply them.

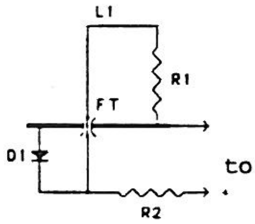
Radar studies of the moon, Quarterly Progress Report, Lincoln Labs, MIT, February 1966.

4.28 Modification to Bird 43 Slugs

D. Mascaro WA3JUF - April 1986

Bird Slugs can be modified to read different power levels for full scale. For example, a 25 Watt slug can be made to read 50 Watts full scale. Changing the calibration resistor inside the slug is all that is needed in most cases. Adjusting the pick-up loop may also be necessary. These slugs can also be modified for different frequency bands. Low power VHF slugs can be used to make UHF or microwave slugs. There are many odd frequency and power level slugs floating around at HAM-fests that are perfect for conversion. All these slugs are basically the same inside. They have a pick- up loop that samples RF which is rectified. A calibration resistor sets the F.S. reading on the 30fA meter movement. The following describes using a 5C element (5W, 100-250 MHz) to make a 5W, 2304 MHz slug. To open a slug: 1. pry off the model # plate with an awl or 2. heat up the top of the slug on a hot plate to soften the glue or 3. Drill and tap a 2-56 hole in the cover and pull it off. Remove the screw inside the cover. This exposes R2 and D1. Next remove the two screws holding the Teflon cover on. This cover encloses the pick-up loop L1 and a load resistor R1. Remove L1 (2 turn coil) and the plastic coil form by cutting it out with a diagonal cutter. Remove calibration resistor R2. Replace L1 with a brass strip as shown. Replace R2 with a 3K3 resistor. R2 can be adjusted by using a resistor of lower value and filing a groove in the carbon to raise the resistance. The size and placement of L1 and the value of R2 was found experimentally as follows: I replaced the calibration resistor R2 with a 10K, 10 turn trimpot. Then different sizes of brass strips were tried. The slug is partially assembled each time and checked in a Bird 43 which is connected to a calibrated load and a HP power meter. The shape and size was adjusted until both the F.S. and linearity were correct. Reasonable tracking can be achieved by trial and error. Lastly the directivity is checked with the slug in the reverse position. The accuracy and linearity depend on how long you spend adjusting L1 and R2. Performance is at least as good as my other slugs. Reassemble the slug and check it's performance again. Readjust R2 if calibration is off. Change the Model # plate to indicate the correct frequency band on you are done. Many inoperative slugs can be repaired rather easily. Dropped slugs usually have a broken L1 coil. Some have bad solder joints. Don't be afraid to open one up. It is no good if it's broken anyway.

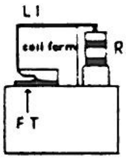
Figure 4–20: Modifying Bird 43 Slugs



to meter

L1 Pick-up coil or loop.
R1 Load resistor.
R2 Calibration resistor.
FT Button feedthru cap.

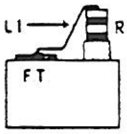
Bird 43 slug schematic



Bird 5C slug.

Remove L1 and coil form.
Remove R2 inside slug housing.

Replace R2 and L1 as shown.



L1 0.65" x 0.050" x 0.010"
thick brass strip shaped as
shown between FT and R1.

R2 3.3K Ohm 1/2 watt
adjusted as nescessary.

4.29 Study in Monkeys Suggests Microwaves Pose No Threat

Gary E. Korte Phd. - May 1986

A Reprint from the "Ophthalmology Times" November 15, 1984

New Orleans - A seven year study on monkeys suggests that the normally encountered intensities of microwave radiation are not harmful to the eye, according to Robert McAfee, Phd., research scientist at the Veterans Administrations (VA) hospital here. During the study, the faces and eyes of monkeys were chronically exposed to microwave radiation of an intensity that was more than 30 times the maximum allowed by the Food and Drug Administration and more than 3 times the intensity shown to cause cataracts in rabbits.

No Anaesthesia Used in Study. "We designed this study with several things in mind" Dr. McAfee told Ophthalmology Times. First of all, we wanted to use animals closer to humans than the rats and rabbits used in earlier studies." Another objective was to study the effects of microwave radiation without the use of anaesthesia. Barbiturates used in the rabbit study, for example, can depress or inhibit the thermal responses of animals , he explained, and one way microwaves may damage tissue by heating it. Finally, "we wanted the animals to administer the microwave radiation themselves, so we could conduct a chronic experiment without the stress of anaesthesia or restraints on the animals." In the study, 17 monkeys were trained to climb onto an apparatus and manipulate a mouthpiece that gave them a drink of apple juice as a reward. Every time a monkey drank, a microwave source was activated and the monkey received a dose of radiation in the face and eyes. The monkeys received from 400 to 900 minutes or more of accumulated irradiation time.

Monkeys Examined Every Six Months. The monkeys were examined by slitlamp microscopy and ophthalmoscopy every six months. "We saw no effects on the monkeys' eyes , including their lenses," Dr. McAfee said. "To avoid needless sacrifice of an animal, histopathology was not performed. We concluded that chronic microwave irradiation had no damaging effect on the eye." The microwave radiation Dr. McAfee used in his experiments ranged in frequency from that of a microwave oven up to that of strong military and aircraft radar. In light of these findings, ophthalmologists need not to worry about microwave damage to the eye, according to Dr. McAfee. "I cannot think of a job or industry in which dangerous microwave exposure would occur, unless someone purposely put his or her head up to an intense microwave source," he stated. "In military, a soldier might be exposed to intense microwave radiation if he is near several aircraft, all with their radar on. However these personnel wear protective goggles and clothing." Dr. McAfee noted that the FDA is reassessing its guidelines on the recommended maximum amount of microwave radiation exposure. "This is presently set at 10mW/cm^2, which our studies indicates is well within the safe range," he said "Officials at the FDA are considering this maximum in half. However in light of our study, such a reduction is not only needless but makes the present maximum imprudent when it is not." Dr. McAfee noted that the present guideline arose as an arbitrary cut from 100mW/cm^2. "That dose, if given over the whole body, will indeed cause hyperthermia," he acknowledged. "This is what initially caused concern among ophthalmologists about microwave radiation." Dr. McAfee's colleagues in this study were: Robert Gordon; MD associate professor of ophthalmology, Tulcane University School of Medicine, Rolando Ortiz-Lugo, a research scientist at the VA hospital, and Richard Bishop Phd., associate professor of electrical engineering at the University of New Orleans. OT

- Gary E. Korte Phd.

4.30 Using A VU meter For Signal Strength Measurements

Rusty Holshouser K4QIF - September 1987

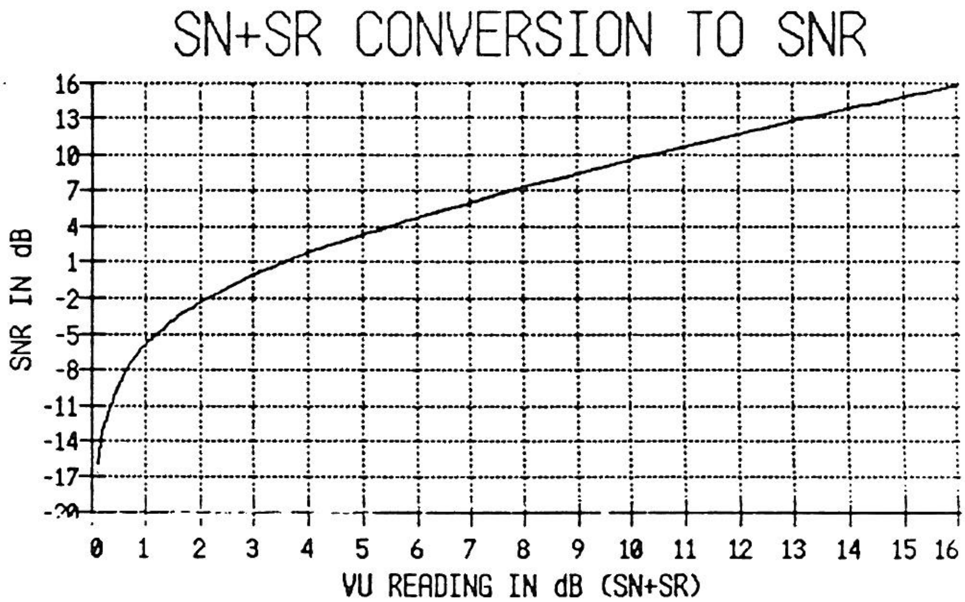
K4QIF proposed a system to make a signal strength report objective rather than subjective which is strongly recommended to be adopted by all. The system is based on:

1. Reading a signal's to noise ratio on a VU meter. (any dB-scale voltmeter will do)

2. Converting the measured SNR to a standard SNR. This conversion depends on the receiver bandpass in use - since narrower bandwidths (BW) yield higher SNR's. A 100 Hz bandwidth was to be the standard. Thus a station using 2 kHz bandwidth would add 13 dB to his measured SNR.
3. Convert dB-reading to S-units by dividing by 3, i.e. 3 dB per S-unit in the EME system. For the 13 dB example the S-report would be 4 rounding to the nearest whole number.

Unfortunately the physics are not quite this simple. The VU meter reading is not SNR but the ratio of signal-to-noise plus signal (SN+SR). The BW conversion (step 2) is only correct for SNR. There is not a significant error in using SN+SR when the ratio is large, but when the ratio is small (7 dB or less), SN+SR must be converted to SNR for an accurate result. Consequently to make K4QIF's system work, an additional step must be added between steps 1 and 2 which involves converting the measured SN+SR from the VU meter to SNR. This can be accomplished by using the graph shown below. The SN+SR is entered on the horizontal axis and the corresponding SNR read on the vertical axis. For example a 3 dB SN+SR VU meter reading would correspond to an approximately 0 dB SNR. For a 2 kHz bandwidth receiver, this would equal, a 13 dB standard SNR or an S4 report.

Figure 4–21: VU to SNR Conversion Chart



4.31 A Sky Noise Chart

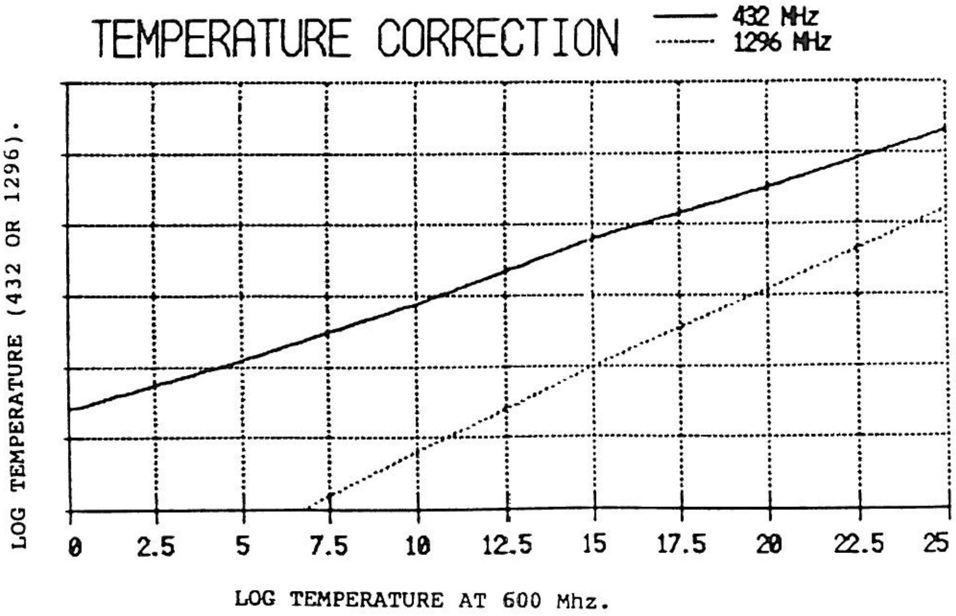
Allen Katz K2UYH - June 1987

The Sky Noise charts presented here will enable you to determine the sky noise your antenna is seeing at any time of the day. To use the chart, you should make a clear plastic transparency of the sky map part. This can be done on many duplicating machines. Lay the (clear) map over the accompanying grid with its centre over the altitude number corresponding to your lattitude. You may find it convenient to put a pin through the centre of the map around which it can be rotated. Line up the time of the outside diameter of the map (corresponds to local solar time) with the date on the outside diameter of the grid. The chart now shows the sky temperatures of your location.

The numbers on the east to westline are azimuth angles - 180° is due south. The altitude axis numbers are the elevation angles. Thus the noise level at 180° azimuth and 20° elevation is the noise shown on the map at the intersection of these 2 lines. This corresponds (for central northern lattitudes) to roughly the centre of the Milkyway at 04:30 local time on April 11th. The curve with dates on it, on the sky map, corresponds to the position of the Sun at different dates.

The numbers shown in the charts are actually 10 $log(T)$ in °Kelvin of the temperature received by an antenna with a 2° - 3° beamwidth at 600 MHz. To correct the values shown for other beamwidths add 6-20 $log(B)$ where B is the 3 dB beamwidth of your antenna in degrees. The resulting value V may be converted to a temperature in °Kelvin by the equation $T = 10^{(V/20)}$. To correct V for 432 and 1296 MHz use the graph shown in Figure 4–22. Then convert V to temperature.

Figure 4–22: Noise chart temperature conversion



4.32 Polarisation Error

Allen Katz K2UYH - February 1988

Figure 4–25 illustrates the geometric rotation on a received signal from central Germany as a function from local zenith and moon declination at our QTH. The angle is taken as counter clock wise positive (trig angle convention), looking at the front of the receive antenna. Considerable more rotation is shown for the higher northern moon declination. You can also see the low rotation angle near moonrise that K1FO refers to, and a second zero rotation angle near zenith.

Figure 4–23: Noise Chart Part I

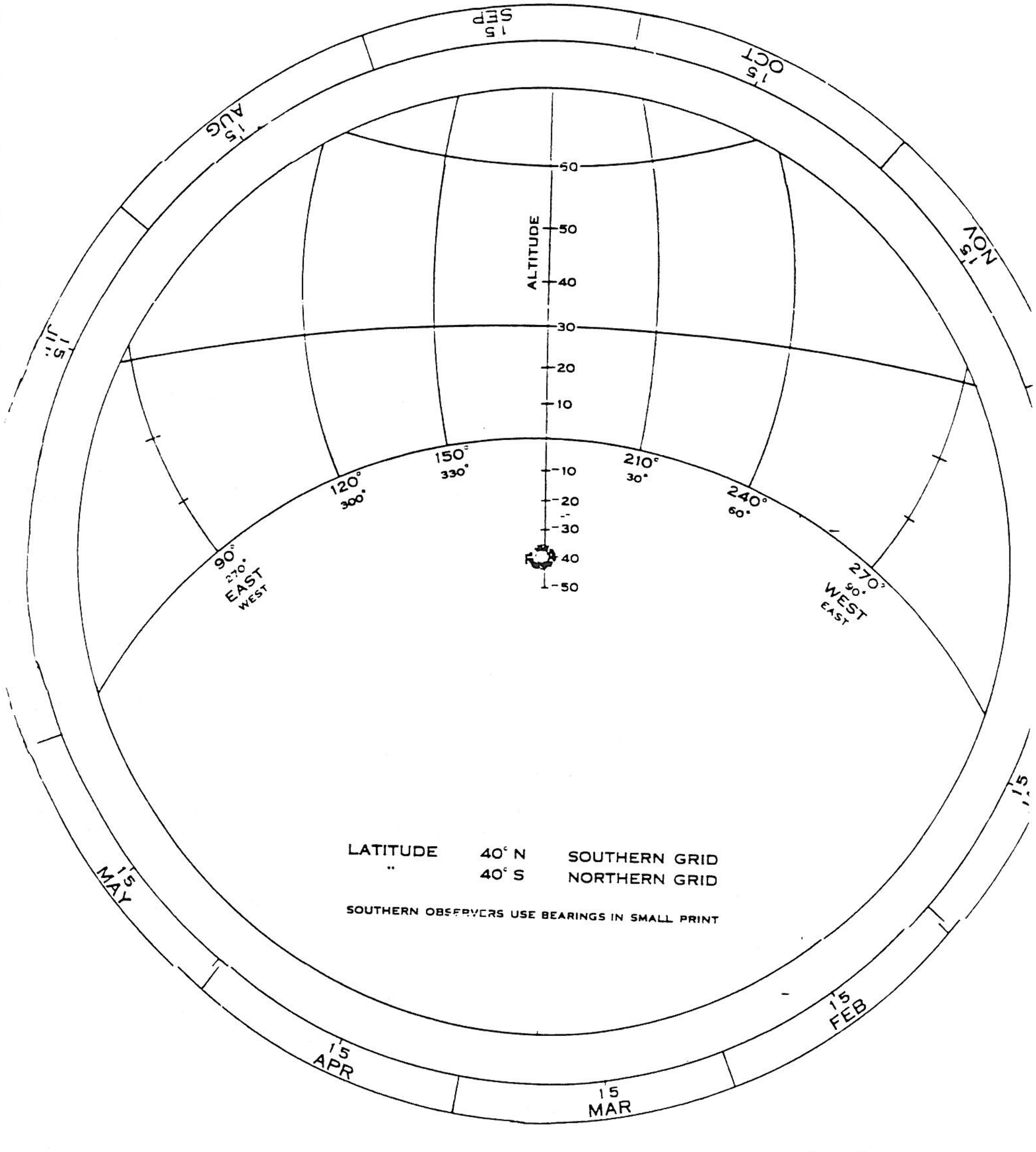


Figure 4–24: Noise Chart Part II

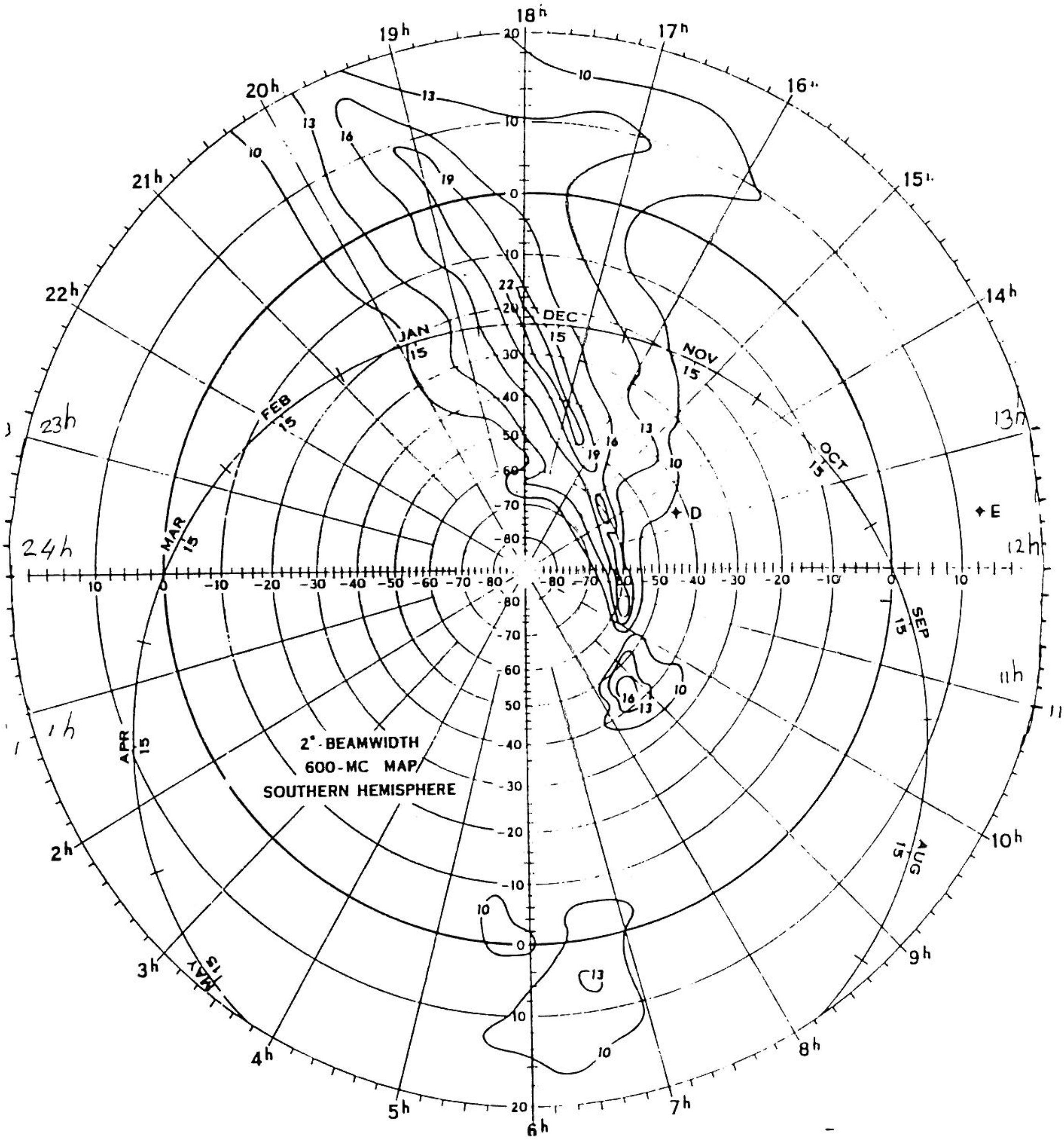


Figure 4–25: Polarisation Angle EUR - NE USA

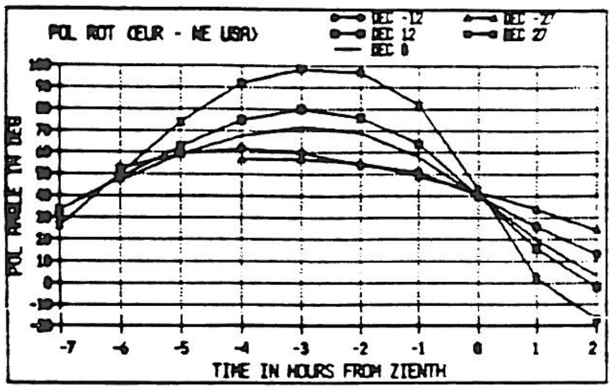


Figure 4–26: Polarisation Angle EUR - NE USA

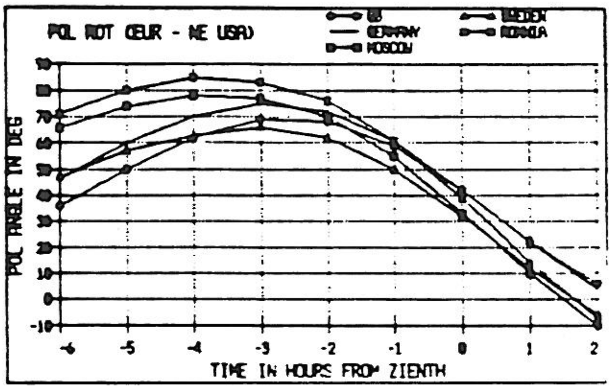


Figure 4–27: Polarisation Angle NE USA - JA

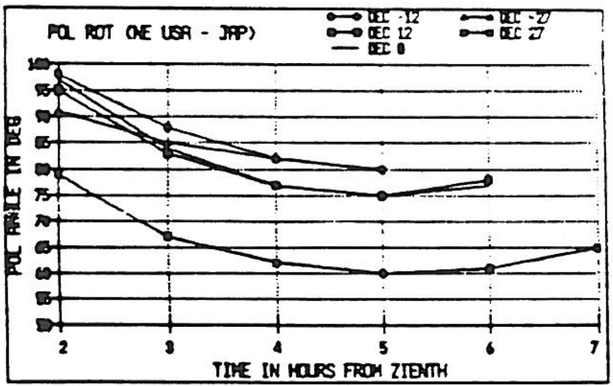
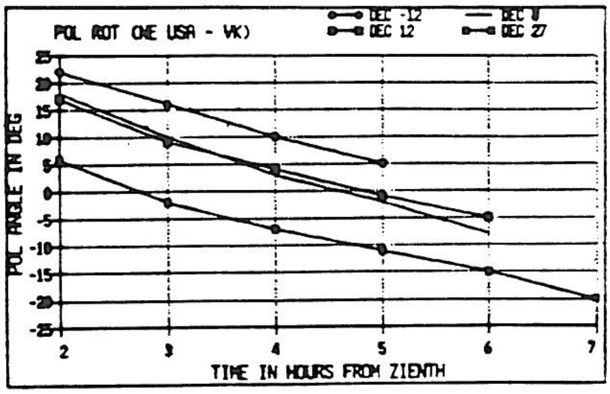


Figure 4–26 shows how location affects the angle. All the curves are for a declination around 12°. You will see that stations to the east have more rotation near moonrise. Figure 4–27 shows the rotation on signals from Japan. This path is considerably different. The figure clearly shows the advantage of a vertical polarised array if Faraday is not significant. The path to Australia (Sydney) shown in Figure 4–28 is still different. Here if Faraday rotation is small, there is little polarisation miss-alignment.

Figure 4–28: Polarisation Angle NE USA - VK



4.33 EME Signal Polarisation

Michael R. Owen W9IP/2 - June 1988

The accompanying graphs in Figure 4–30 are based on formulas provided by Tim Pettis KL7WE. They predict the extent to which linearly polarised will be coplanar, and the loss to be expected when they aren't. They are based entirely on geometrical considerations and useful only when Faraday rotation is not active. (or when it is 180 or 360°) The geometric polarisation angle of horizontally polarised EME antennas, relative to the earth axis is given by:

$$cos_{pol} = cos_{lat} \cdot sin_{az}$$

Where:

- pol - geometric polarisation angle (0° if parallel to the earth axis, 90° if perpendicular.)
- lat - the stations latitude
- az - the moon's current azimuth.

To find the polarisation error between two stations, calculate the polarisation angle for each station and take the difference. Add or substract 180 if necessary to bring the value between +90 and -90. Loss resulting from cross polarisation is given by:

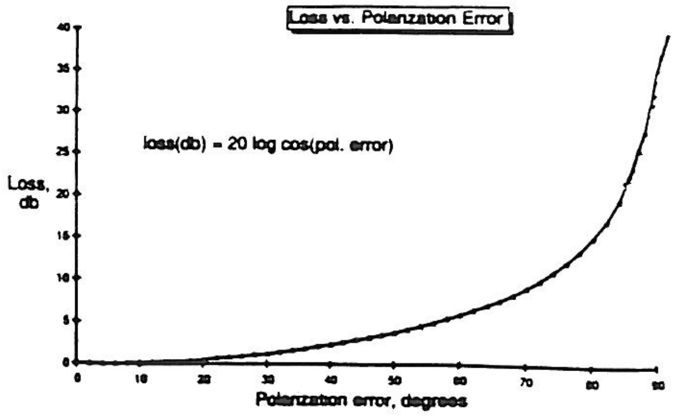
$$loss_{dB} = 20log_{10}cos(pol.error)$$

Loss is zero when the polarisation error is zero (i.e. when the antennas are parallel). Loss rises slowly, so that 45° cross polarisation costs only 3 dB.

By 60° however the loss is 6 dB and it rises very rapidly beyond that. This accounts for the sharp null and broad peak in signal strength observed by the lucky stations with rotatable polarisation.

The graphs in Figure 4–30 show how polarisation error varies with time during the mutual window between various areas. U.S.A. East Coast stations have low loss into Europe only during their moonrise and European moonset, high loss at all times into Japan, and low loss into Australia. U.S.A. West Coast stations have essentially no European window. Europeans generally have great difficulty working Japan.

Figure 4–29: Signal Loss vs. Polarisation Error



The graphs assume that both stations are horizontally polarised. If one station is vertically polarised, each polarisation error curve is inverted (by subtracting 90°) Doing this for North America- Europe and North America-Japan links shows a long wide window of low loss. North American stations wanting to work Europe and Japan should install their antennas vertically polarised. However there is a price: it will be very difficult to work North American and Australian stations.

4.34 CW Noise Smoother

Yuu JM1MCF - February 1989

Yuu reports that this Noise Smoother provides a significant improvement in copiability. The improvement does not approach the theoretical limit due to the fact that:

1. The received noise is band limited and thus correlated.
2. 432 MHz moon signals have a significant bandwidth. Even a 30 Hz modulation will cause several dB's loss.
3. The filter generates it's own noise and distortion.

Despite these facts Yuu feels that there is a real improvement, although he cannot give it a dB value. He also suggests and alternate approach of multiplying the delayed signals rather than adding the signals, but this is significantly more complex to implement.

Piero I5TDJ, who also has very promising results with the Noise Smoother, used switched capacitor delay circuits rather than the Panasonic MN3006 bucket brigade IC delay chips used by JM1MCF, as these devices were not available in Italy. See Section 4.37.

Figure 4–30: EME Signal Polarisation

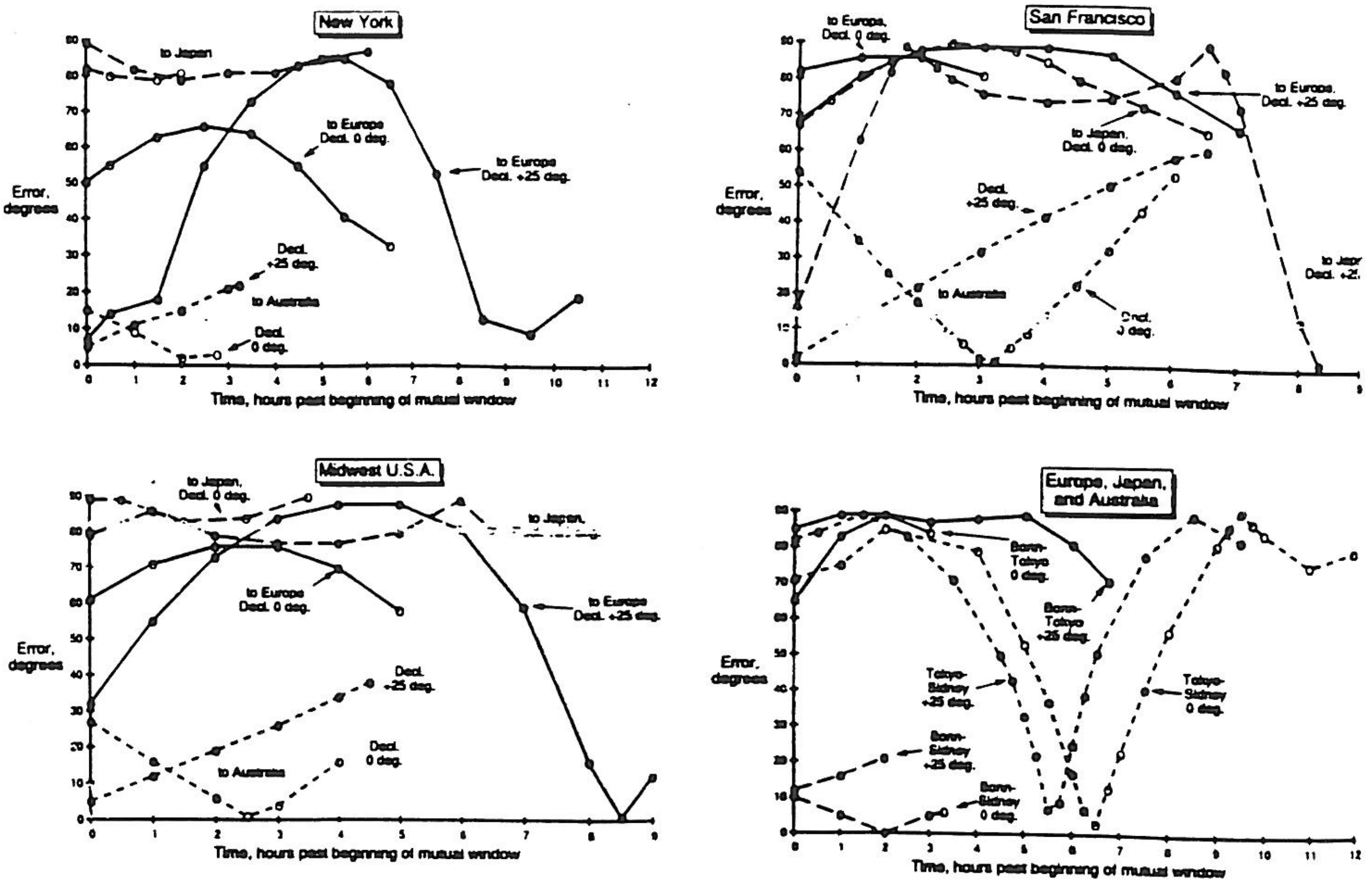
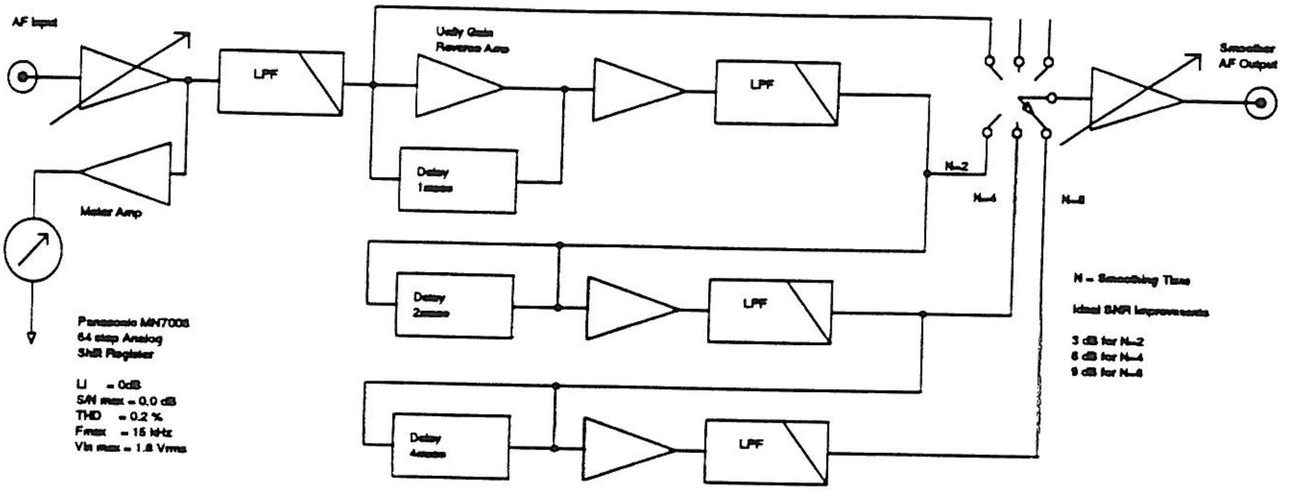


Figure 4–31: CW Noise Smoother Block Diagram



4.35 9913 Connector Conversion

Scott Mathewson WA3FFC - February 1989

Connector conversion from 9913 coax to 1/2" Heliax.

1. Cut end of heliax straight. Remove 1-1/2" of plastic jacket. Remove 1" of copper heliax outer jacket.
2. Drill nut from UG21 to fit over heliax outside conductor. Approx. 9/16" some types may vary. Use a drill press, a hand drill won't work.
3. Drill centre conductor to fit old centre conductor approx. 1/4" deep. Insert a short (1" or so) section of old centre conductor from 9913. Wrap with copper tape to spice and solder.
4. After preparing the centre conductor trim the new centre conductor so that 0.2" of distance exists from the end of the heliax jacket to the rear of the centre pin and solder. Clean melted foam and flux with a knife.
5. Screw nut into barrel of UG21. Slide the assembly onto the heliax until the depth of the centre pin is correct. Solder the nut to the outer jacket with a torch and cool with a damp cloth to prevent damage to the rubber gasket.
6. Remove the UG 21 barrel inspect for excess flux and solder reassemble coat with silicon seal and install heat shrink tubing over connector to waterproof.

Figure 4–32: CW Noise Smoother

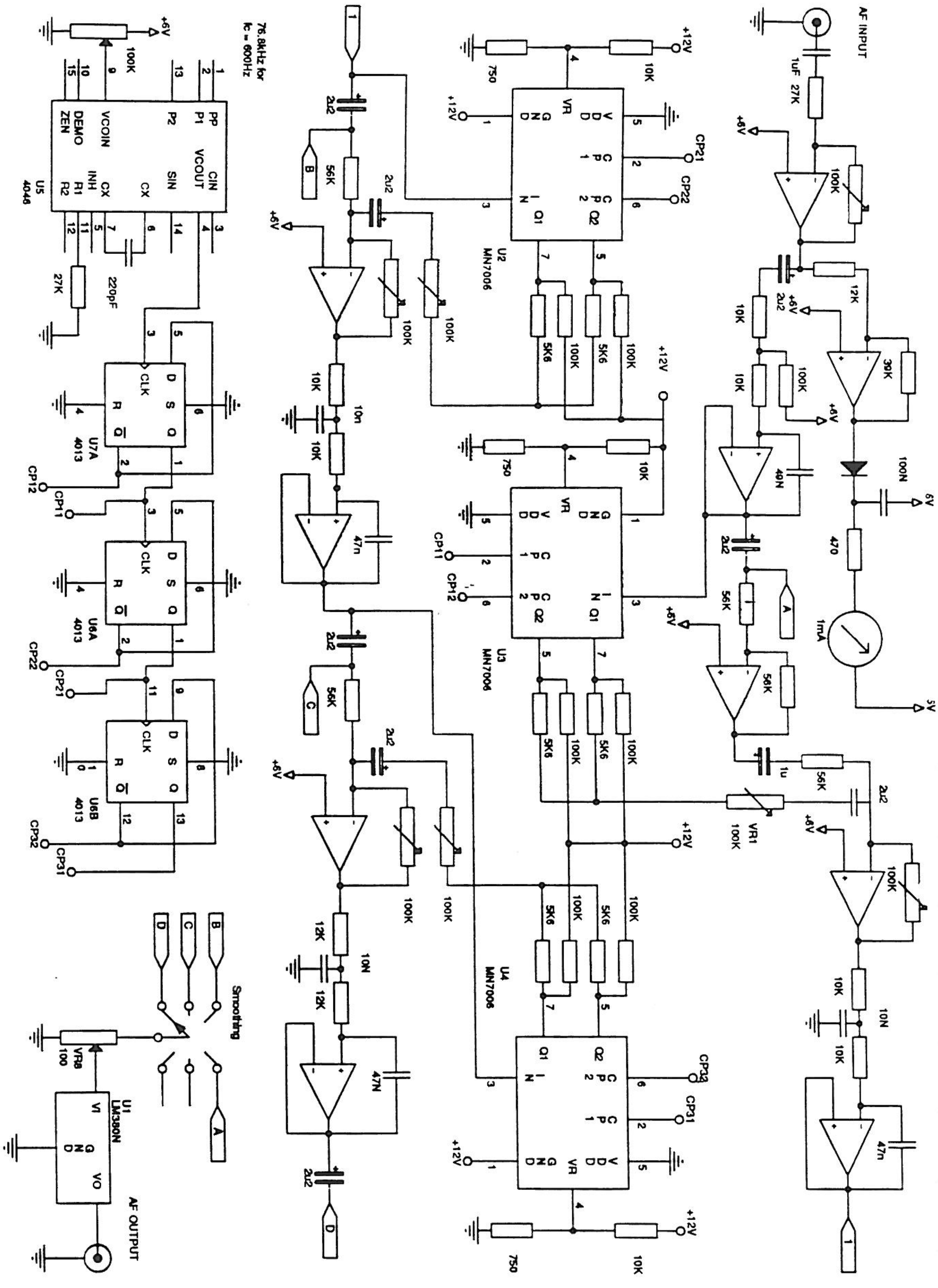


Figure 4–33: 9913 Connector conversion

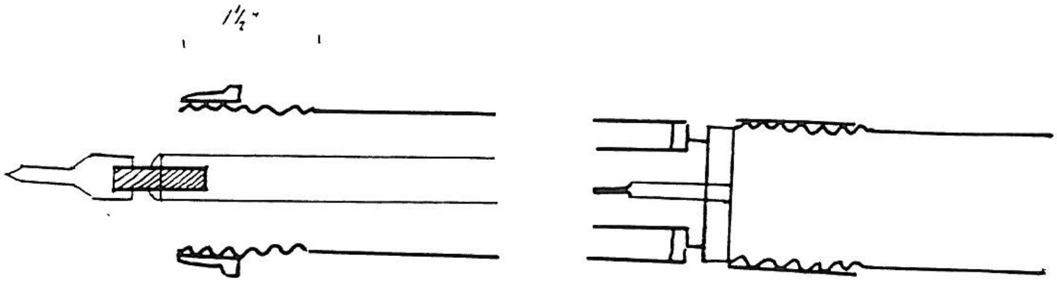
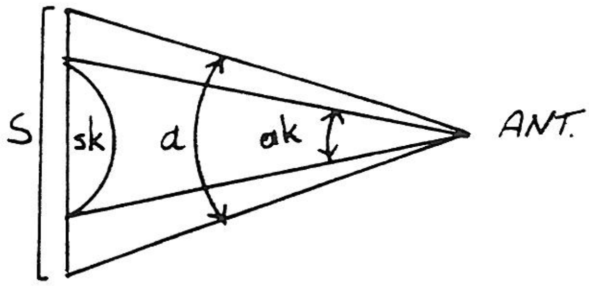


Figure 4–34: Geometric model moon noise measurement



WA3FFC is using this system for all 10 lines and jumpers for the amplifier with no problems. Changing from 9913 to 1/2" heliax netted 1.5 dB increase in Sunnoise without spending $500.

4.36 Estimating Moon Noise

Paul Chominski SM0PYP - March 1989

Sometimes people report quite high values of the moon noise. Let's try to calculate how much moon noise we can really expect. Figure 4–34 shows the model we use in our calculations, where:

ak - angular size of the moon seen by the antenna
a - main lobe of the antenna
sk - surface of the moon
s - surface seen by the antenna at the plane of the moon
r - distance moon antenna

Temperature measured from the sky without the moon:

$$T_{sky} = T_s + T_{rx} \tag{4–5}$$

Where T_s is the sky temperature and T_{rx} is the noise temperature of the receiving system with the antenna.

The temperature measured from the moon:

$$T_m = T_{s'} + T_{rx} + T_{moon'} \tag{4–6}$$

Where $T_{moon'}$ is the moons temperature measured by the antenna:

$$T_{moon'} = T_{moon}(\frac{sk}{s}) \qquad (4\text{–}7)$$

Where T_{moon} is the noise temperature of the moon itself which is approximately 240°K in the frequency range 400 - 2500 MHz.

$$T_{moon'} = T_{moon} \cdot \frac{r \cdot tg \cdot (\frac{ak}{2})^2}{r \cdot tg \cdot (\frac{a}{2})} \qquad (4\text{–}8)$$

$T_{s'}$ will be lower than T_s because the moon screens some part of the sky behind it. For simplification lets assume that $T_{s'} = T_s$. For amateur size antennas this will only cause a marginal higher calculated value of the expected moon noise. The noise ratio measured by receiver expressed in dB will then be:

$$F = 10 \cdot log(\frac{T_m}{T_{sky}}) \qquad (4\text{–}9)$$

Finally inserting (4–7) and (4–8) we obtain:

$$F = 10 \cdot log(1 + \frac{T_{moon'}}{T_{sky}}) = 10 \cdot log(1 + \frac{T_{moon}(\frac{tg(\frac{ak}{2})^2}{tg(\frac{a}{2})})}{T_{sky}})$$

Lets take a few examples:

An 8 Yagis system for 432 MHz having an 8° main lobe with a very good receiving system at -80°K and sky temperature T_s is 15°K. From (4–8) we will get:

$$T_{moon'} = 240K(\frac{tg(0.25)^2}{tg(0.4)}) = 0.93K$$

The moon noise we will measure (4–9):

$$F = 10 \cdot log(\frac{80 + 15 + 0.93}{80 + 15}) = 0.042dB$$

For a 10 meters dish on 1296 MHz having a main lobe of 1.9° and same parameters of the rest of the system:

$$T_{moon'} = 16.6K \quad and \quad F = 0.7dB$$

As a last example let us take a large radiotelescope 50m in diameter having main lobe of 0.22° on 2304 MHz, and the same parameters of the receiving equipment. When the main lobe is smaller then the angular size of the moon, we can simplify (4):

$$F = 10 \cdot log(\frac{T_{rx} + T_{moon}}{(T_{rx} + T_s)}) = 5.27dB$$

As a conclusion I think that the noise higher as expected, observed by many EME ers including myself, is coming from other cosmic noise sources located within the main lobe of the antenna.

4.37 Multiple Time Delay Filter

Piero Moroni I5TDJ - May 1989

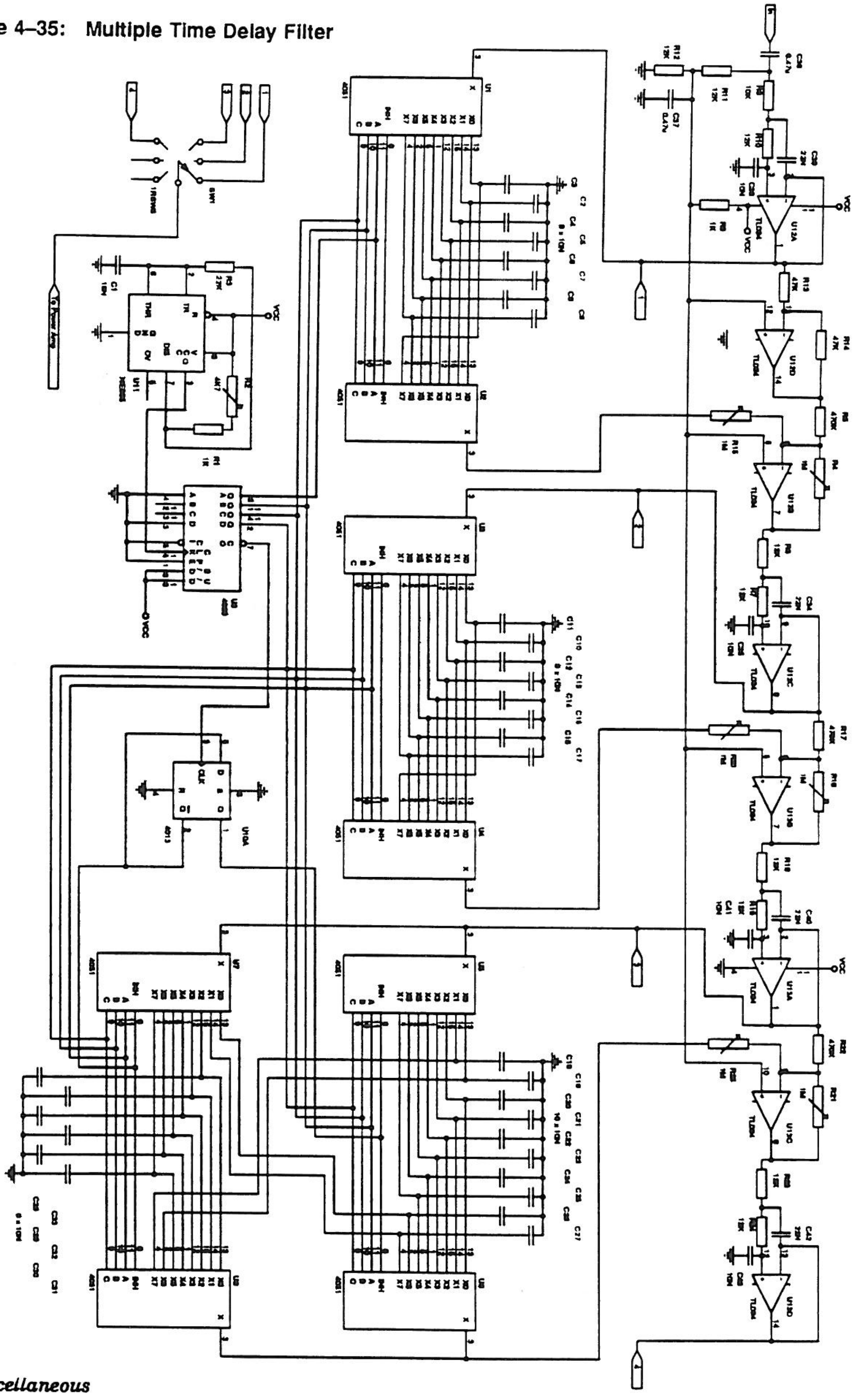
4.37.1 Description

This audio filter was derived from the schematic given by JM1MCF. Since I was unable to find the "Bucket Bridade Delay" integrated circuit MN3006, which has been used by JM1MCF, I have used the analog 8 steps multiplexer 4051. Using two 4051 and 8 capacitors, we have a time delay 8 times the clock frequency; with four 4051 and 16 capacitors, a time delay of 16 times the clock frequency can be obtained. I believe that this way is not as good as the JM1MCF circuit where the same delay is made in 64 steps, I have used three different time delays, as in the original circuit. The first is a half period long (at the wanted frequency), the second one period, the third two periods. The clock frequency is generated by a 555 and can be adjusted to move the filter centre frequency from about 450 Hz through 100 Hz. A 4029 binary 4 bit counter drives the first 4051 couple form its Q1-Q2-Q3 outputs, while the Q2-Q3-Q4 outputs are used to drive the other groups of 4051.A 4013 a D flip flop, driven by the 4029 "carry out" switches the two 4051pair of the last delay circuit. The first two pair of 4051 are interconnected to get a 8 step delay; the right 4051 input no. 2 is connected to the left 4051 output no. 1 and so on. Due to the fact that the signal is sampled only 8 times per period, the resulting time delay is 7.5 times the clock period. To get the wanted delay at a certain input frequency, we have to decrease slightly the clock frequency; the effect to the first delay, which is only half period, is only 0.25 times the clock period, giving a negligible error. The last delay for this lower clock frequency, becomes two periods plus 1/16 of the input frequency. Properly wiring the last four 4051, we make them to delay the signal 15 clock periods, which is very close to two signals periods. This is the reason why the last four 4051 are not connected the same way as the first two groups. The input signal after a low pass filter goes to the first delay circuit. The delayed signal is added to the undelayed signal, phased out by 180°, to have them adding in phase. Another low pass, filters out the delay sampling frequency. The next two delay blocks use similar adder and low pass filter. The signal can be picked up after the first low pass filter (no delay) or after the first, second and third delay and can be amplified to get the wanted listening level. Adjusting the clock frequency we change the filter centre frequency. I have increased the low pass filters cut-off frequency, with respect to the JM1MCF design, to have a wider range of centre frequencies.

4.37.2 Adjustment

To properly adjust the circuit, it is necessary to have an audio oscillator and a dual trace scope. Set the audio oscillator at 600 Hz and apply 1V peak to peak to the filter input. With the scope connected to 4029 pin 6 (Q1), adjust the clock to read 9600 Hz (16 times the input frequency). With trace 1 to point 1 as reference the signal at pin 3 of the second 4051 shall be delayed half a period. Move trace 2 to point 2 and the input signal to 1200 Hz. Adjust Vr1 for a null at point 2. Move back the input signal frequency to 600 Hz and adjust Vr2 to have 1Vpp at point 2. Connect trace 2 of the scope to pin 3 of the fourth 4051 and trace 1 to point 2. The 2 signals should be nearly in phase (one full period delay). Slightly readjust the clock frequency to have 360° of delay; the scope in X-Y mode will be helpful. Move trace 2 to point 3 and set the input signal to 900 Hz. Adjust Vr3 for a null at point 3. With the input frequency back to 600 Hz, adjust Vr4 to have 1Vpp at point 3. Connect now trace 1 to point 3 and trace 2 to pin 3 of the upper right 4051, the signals will be nearly in phase (two full periods delay). With trace 2 to point 4 and the input frequency at 750 Hz, adjust Vr5 for a null. Then with the input frequency back to 600 Hz, adjust Vr6 for 1Vpp at point 4. To verify the filter operation, with the scope connected to point 4, move the input frequency. There will be nulls at 150,300,450,750,900,1200 Hz and so on. In other words, the filter response has nulls at +/- 1/4, 1/2, 3/4 and 1 times the centre frequency.

Figure 4–35: Multiple Time Delay Filter



4.38 Evanescent Mode Filter

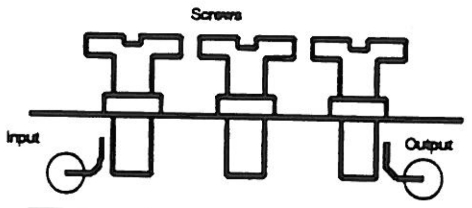
Allen Katz K2UYH - September 1989

This type of filter is not well known in amateur circles but is extremely easy to fabricate and relative easy to tune. EM filters are based on the fact that a waveguide below its cutoff frequency appears a reactive element. By restricting the size of a waveguide at different points it is possible to make it act as if it were a series of resonant elements and thus function as a bandpass filter. The resultant filters tend to have more insertion loss than the popular comb and interdigital filters and consequently would not be the best choice for an input filter of Preamp. On the other hand, EM filters provide sharp skirt and very high out band signal rejection. They are well suited for filtering in a receiver after the first Preamp; particularly for the rejection of image signals and noise. Image rejection is a problem on 10 GHz were some of the available transverters provide inadequate rejection especially when proceeded by several stages of high gain preamplifiers. The sample filter shown here was designed for this purpose.

The basic form of an EM filter is shown in Figure 4–36. It consists of a number of approximately equal diameter and height conductive posts inserted into a waveguide operated beyond cutoff. Any closed conductive tubular shape can be used as a waveguide; rectangular, square or round tubing work fine. The filter shown is made from 0.5 inch copper water pipe. By rule of thumb, a waveguide 3 sizes smaller than the operating frequency of the filter is a good choice. Too small a size will increase insertion loss. Too large a size will bring the pass mode of the waveguide close to the passband of the filter. (As is the case with all transmission line element filters, there exists higher frequency bands where the filter will cease to attenuate and again pass signals.) The spacing of the posts is determined by formula for the type of bandpass filter being produced. To easy this process I have written a short basic program to calculate the posts spacings. The program also helps in the choice of waveguide dimensions and provides suggested post height and diameter. (If a round tube is used, assume the A and B dimensions of the guide equal the diameter of the tube. This provides satisfactory results.) The program requires the normalised low pass filter element values. These are available from tables in a number of books. The values for a 3 pole Butterworth are 1, 1.414, and 1. Computer programs are also available which provide filter elements. I have written another program FILT-ELE, see Figure 4–37, which provides values for Butterworth and Tchebechve filters.

The post diameter is not critical. Standard screws are normally used for the posts. Choose the closest conveniently available screw size. Drill holes through the waveguide tube sufficient to pass the screws and solder the nuts to the outside of the waveguide to hold the screws in place. Insert the screws to the suggested height. This height will be adjusted for the desired response when the filter is completed.

Figure 4–36: Evanescent Mode Filter



Coupling in and out of the filter is accomplished by capacitive probes. Coaxial connectors are mounted through the waveguide walls near the first and last posts, and short lengths of wire or copper ribbon are run from the connectors to the vicinity of their respective post, see Figure 4–36. The wire post spacing will be adjusted for the best filter response. The length of the waveguide should be extended at least a quarter wavelength beyond the first and last post. The further the guide extends, the less the signal leakage. The ends may be left open, or they may be sealed to reduce further leakage.

There is nothing more required to produce an EM filter. Once the filter is fabricated adjust the posts heights and input/output probe spacing for the desired response. The 10 GHz filter shown provided more than 70 dB of image rejection with a 144 MHz IF. I have used EM filters on frequencies from 400 MHz to above 12 GHz. At lower frequencies filter gets large but response obtained is equally impressive.

Figure 4–37: Program for Butterworth and Tchebechve Filters

```
10 CLS: PRINT "EVANESCENT MODE FILTER DESIGN PROGRAM": PRINT
20 INPUT "WHAT IS CENTER FREQUENCY IN MHZ" ;FO: FO=FO*1000000!
30 INPUT "BANDWITH IN MHZ";BW: BW=BW*1000000!
40 LAMDAO=3E+10/FO
50 PRINT: PRINT "ENTER ALL DIMENSIONS IN INCHES": CM=2.54
60 PRINT: LG=1.2*LAMDAO/2/CM
70 PRINT "WHAT IS PROPAGATING WAVEGUIDE DIMENSION, AP (";LG; ")": INPUT AP
80 PRINT "WHAT IS PROPAGATING WAVEGUIDE DIMENSION, BP (";LG/2; ")":INPUT BP
90 BP=BP*CM: AP=AP*CM
100 INPUT "WHAT IS EVANESCENT WAVEGUIDE DIMENSION A(<AP/3)"; AE: AE=AE*CM
110 INPUT "WHAT IS EVANESCENT WAVEGUIDE DIMENSION B(A/2)"; BE: BE=BE*CM
120 LAMDAC=2*AE
130 LAMDAO=3E+10/FO
140 R=LAMDAO/LAMDAC
150 P=R^2-1
160 Q=SQR(P)
170 GAMMA=(6.283185/LAMDAO)*Q
180 LO=1.83178/GAMMA
190 DELTA=2/(1+1/(1-(LAMDAC/LAMDAO)^2))
200 INPUT "NUMBER OF COMPONENTS FROM FILT-ELE PROGRAM";NUM
210 FOR N=1 TO NUM
220 PRINT "ENTER G";N:INPUT G(N)
230 NEXT
240 WO=FO*6.2831853# :PRINT
250 FOR N=1 TO NUM-1
260 RAD=0.5*WO*DELTA*SQR(G(N)*G(N+1))/(BW*6.2831853#)
270 LR=LOG(RAD+SQR((RAD)^2+1))/GAMMA
280 PRINT "L"; N;"(POST SPACINGS) =";LR/CM
290 NEXT
300 POSTDIA=0.2*AP
310 POSTH=0.5*BE
320 PRINT "POST DIAMETER =" POSTDIA/CM
330 PRINT "POST HEIGHT =" POSTH/CM
340 END
```

4.39 Operating with Concern to Frequency

Allen Katz K2UYH - December 1989

One question frequently asked is on what frequency should I transmit during a sked, the listed frequency of the schedule or the frequency which will cause my echoes to be heard on the listed frequency? In the past most people transmitted on the sked frequency. But as information on Doppler shift has become available, VK3UM's Moon program is ideal for this purpose, the trend has been to put the transmitter on a frequency where it will be heard on the skeds frequency. To do this you most off-set your transmitter frequency to compensate for the Doppler shift between you and the skeds station. This shift is the same in both directions of the path, but is not necessarily the same as the Doppler shift of your own echoes. I suggest that we all try to transmit so as to make our signals to be received on the skeds frequency. (Consistency is not too much of a problem on 432 with a maximum Doppler frequency error of about

1.2 kHz, but as one goes up in frequency the error becomes very significant -3.6 kHz on 1296 and 36 kHz on 10 GHz!)

When you hear another station (his echoes), if you transmit so as to put your echoes on the same frequency, the other station will hear you on the same frequency as he hears his own echoes. (Note this does not mean that if you set your transmit frequency so that your echoes fall on the skeds frequency, that the other station will hear you on the skeds frequency.) When operating random, its a good idea to off-set your transmit frequency so that your echoes fall on the same frequency as you are listening on. This way, when you hear a station and respond to him, he will hear you on the same frequency as he hears his own echoes. (If you have an FT726, or similar transceiver, you can use the shift mode to automatically off-set your transmit and receive frequencies by the required amount.) The required shift is the opposite of the Doppler shift of your received echoes.

If in the skeds case, both stations set their transmit frequencies so that each will be heard on the skeds frequency at the opposite end of the path, then both should be heard on the sked frequency. If one station transmits so that his echoes fall on the frequency of the signals he his hearing, then the other station will not hear him on the skeds frequency but on the frequency where his (own) echoes fall.

4.40 Operating with Concern to Frequency Revisited

Allen Katz K2UYH - January 1990

Our comments in the December Newsletter, suggesting that stations adjust their TX frequency so that their echoes fall on the sked frequency as heard by the station they are transmitting to, raised quite a bit of negative comments. In general it was felt that such a scheme was too complicated and could lead to confusion and error. It was further pointed out that many stations do not have the computer power necessary to make the two station Doppler calculations required by the proposed procedure. In retrospect, I am afraid that the critics of my proposal are right and that it is best that we all continue to follow the present practice of always transmitting on the sked frequency, regardless of the Doppler shift.

This means that the station transmitting to you (assuming he is following this procedure and is on the right frequency) will not be heard on the sked frequency, but will be shifted by an amount equal to the Doppler shift between you and him. This frequency shift will not necessarily be equal to the Doppler shift of your own echoes. If the station you are scheduling is to the east, and the Moon is between the two of you, your own echoes will be shifted higher in frequency, while those of the sked station (as heard by you) will be somewhere between the frequency of your own echoes and the actual sked frequency. When the sked station is to the west and the Moon is between the two of you, the shift will be lower in frequency with the sked station's signal located between the frequency of your own echoes and the actual sked frequency.